DIGITAL TEXTILES
TACTILE EXPRESSIONS IN A VIRTUAL ENVIRONMENT
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SHEER CHECK
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1. Abstract

What if fibres were strings of numbers, arrays of digits turned into threads, not taking a specific form but constantly evolving. An increasing online presence and virtual experiences are shifting the understanding and definition of materiality. This work starts with a focus on textile expressions in a virtual world. It is built on new ideas on material thinking, with an emphasis on the divergence of aesthetic expressions. It explores the crossing between traditional craft and complex computer-generated structures. The idea is to reimagine how textiles are designed and made. The aim is to broaden the textile design field by exploring the definition of textiles through digital materiality, focusing on computer-generated images and surfaces in 3d software.

Keywords.

Design, textile, digital textile, virtuality, 3d software
2. Introduction to the field, idea and state of the art

2.1 Field of Research: What is a textile?

Before computers, weavers were coding their looms with punch cards. Holes in paper decided the threads journey through the loom and how bindings and patterns emerged in the weave. Today, computers are doing the coding for us. Algorithms play a big part in our everyday life.

Throughout history, materials have changed and evolved with technology. Depending on what period of time, their value and status differ. Regardless of time, technology has been an important piece of which the relationship between human and materiality is recorded and reshaped. Leonardo (et al. 2012) suggests that we are at the beginning of a new world, an artificial world that is full of digital artefacts that are infinitely evolving. Yoo (2010) points out the demand of new approaches to this new virtual world and its evolving materiality. When creating in a digital environment it is not set in the same way as for example creating a weave in a loom. It has another kind of materiality that is forever changeable and is, as Yoo puts it, "the unique materiality of digital technology".

Textile material development in recent years includes knowledge within nanotechnology, electronics and computer science. This is changing the appearance and definitions of textiles and means that there is a possibility to design unprecedented material properties and expressions (Bergström et al. p 156, 2010). "Such materials are only rarely mass-produced, existing as a realm of potential rather than as physical samples".

A textile could be defined as a fibre, filament, or yarn used in making cloth (Merriam-Webster.com Dictionary, 2020). Further, a cloth is a material usually made by weaving, felting, or knitting natural or synthetic fibres and filaments (Merriam-Webster.com Dictionary, 2020). In other words, a textile is a structure of intertwined units that together create a whole. The units have a length and a thickness depending on what kind of technique is applied. The units can also in themselves consist of smaller units. A textile is defined by its materiality and technique.

Textiles have a texture and a surface, with certain properties such as tactility and flexibility. If we juxtapose this to a virtual setting, virtuality can be defined as not physically existing but made by software to appear to do so (OUR 2019). A digital 3d model is a mathematical representation of data existing in three dimensions visualized through software. Not unlike a textile, the 3d model is built out of vertices (bindings), edges (fibres) and faces (surfaces), that together form a mesh. In other words, a 3d model can be defined as a structure of intertwined units that together create a whole.

From a historical perspective, the current understanding and definition of textiles are based on craft traditions and industrialized society. However, an increasing online presence and virtual experiences are shifting the understanding and definition of materiality. Our preconception about what a surface is, is changing (Briggs, 2011). Introducing textiles into a virtual environment would mean a change of tools and an adjustment of the medium as it is currently defined, a change in the current understanding. As McCullough (1996) points out, "the action of the hands, eyes, and tools must be mediated. Our personal knowledge and skills must be given a habitual setting for practice". In the understanding of a medium within traditional material craft, it is often articulated in terms of structure and the understanding of structure is learned through experience (McCullough, 1996).
What if the actual fibres were strings of numbers, arrays of digits turned into threads, not taking a specific form but constantly evolving. This would mean as previously mentioned that other approaches to materiality is possible and also opens up the definitions of what a textile could be, or will become (Bergström et al. 2010). Tactility is one of textile mediums' apparent and basic properties. If one would take the tactility away, what would happen? We would only have sight and "lived" experiences to understand the textile. Then the medium, the textile, would no longer be defined by the technique and the materiality but rather by the structure of the software and the aesthetic, the tactile expressions. Imagine this approach when exploring what a textile is and put established production techniques aside. "Design is about imagining future possibilities and making things that enable us to live some of these possibilities (Bratteteig, 2010, p.147)."
2.2 State of the Art + Motive

2.2.1 Walking the line between real and unreal

Wang and Söderström (2020) is a design duo that focuses on digital vs physical exploration and fabrication. They have a strong visual language that can be described as a mix of digital and physical objects and materials (figure 2). Foremost in the form of abstract sculptural imagery, set design, visual concepts and 3D printed pieces. Alvarez’s (Penny, 2017) works oscillate between physical limitations and expression, technological innovation and traditions of craftsmanship (figure 1). The focus lies on the creation of tools and processes for the production of objects and architecture.

These two design practitioners have a similar aesthetic but use totally different materials, tools and techniques. While Alvarez uses mostly natural materials, like wood, fibres and clay, his works are manual with his hands and with his tools. Wang & Söderström uses plastics and digital screens in their work, their main tools are computer programs and 3D printers. Both of the studios have a delicate and precise expression regarding surfaces and colours of the objects. Their chosen tools feed the outcome. In relation to this work, the consciously choice of tools and how that effect the outcome is a fundamental part of this works’ design process.

Another common factor is the stretching of reality and defiance of gravity. The human touch, the imperfections that are created when working with the hand is somewhat missing in Wang & Söderströms work, but highly present in Alvarez. Balancing realism and imaginative shapes and textures is another key part of my work.

David Phillip Stearns has worked with a wide range of media electronics to address the many roles technology plays in contemporary society. He addresses both the digital and material world in his artistic practice. He created the project Glitch textiles in 2012 with the intention to “render the subtle structures of our digital reality into intimate, tactile materials” (Stearns, 2021). In other words, he extracts images from the visualization of code and applies them to textiles materials, woven fabrics (figure 3). Moreover, he talks about digital technology and its invisible values. In relation to my work, it is the same idea of reimagining materiality. This work aims to expand on Sterns way of using digital expressions in the context of textiles, except not in a physical material but in a virtual context.
Figure 3: Woven Blanket, Quilt Textiles (Stearns, n.d.)
Echelman (2020) uses custom-braided coloured fibre knotted into netting, Industry looms and recycled netting in her large scale textile installations. Her work creates spaces within an already existing space, it communicates well with wind and lights high up in the sky. The thin lines of the textiles look almost unreal from below.

Computation and software are a vital part of Echelman’s design, she works with engineers, programmers and 3d designers to visualize, calculate durability and construct the pieces. Relevant to this work is the way Echelman uses technology in the design process and how that creates a certain aesthetic, a crossing between traditional craft and complex computer-generated structures (Figure 4). The chosen production technique guides the final shapes. Imagine not needing to relate to the limitation of physical tools and look at these shapes in another scale. The shapes could be a base for a new type of textile, comparable to a loop in a knit or a binding in a weave. The physical materiality of Echelman’s work is not essential in relation to my work.

When it comes to virtual design, another interesting example is the digital fashion house The Fabricant that makes digital-only clothes (Marchese, 2019). They collaborated with commercial brands like Adidas and Puma. A one-of-a-kind digital design made by the company sold for $9500 at a block conference in May 2019 (Roberts-Islam, 2019).

Refik Anadol is a director and media artist (Anadol, 2020). The base of his work is big data translated through AI into artwork which is shown on large scale projection and screens (Figure 5). The way Anadol creates immersiveness through data, often through thousands of images to create one piece, relates to the definition; a structure of intertwined units that together create a whole. Andol and The Fabricant are both at the forefront of digital tools and technology within their field. Contrary to Echelman, they introduce a novel thinking around materiality and data, where immaterial assets are valued differently from before.

Figure 4. Janet Echelman, textile sculpture (Echelman, 2010).
A software is like a big pot of ingredients without any actual cooking time. Workflows and processes are shortened, which means more time for the creative development. Further, to continue to develop a textile language and create new expressions the tools that are used are decisive. As in Alvarez, Echelman and Anadol work, their aesthetic is very much based on the tools they use. Moving away from the traditional textile techniques opens up for the opportunity to discover new expressions.

A call for different perspectives in the merging of textile and technology is brought up by both the designer Ute Ploer⁴ and the research studio PLAY(Hallnäs, Melin, Redström, 2002). This has been seen in the integration of technology in physical materials and the design process, similar to Phillip David Stearns’ and Echelman’s work. The Fabricant and Anadol add another perspective to this call with their focus on digital materiality.

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⁴Ute Ploer, Designer, Higher Seminars, open lecture, Swedish School of Textiles, 20201124.
2.2.4 Abstract images and visualization through creative coding

Serious interest in aesthetics + computation as an integrated activity is evident in all cultures and is manifest in many of the objects, structures, and technologies of the times in which they were created. Regardless of whether the technology is an engraving stick, a loom, a plough, or a supercomputer, the impulse to work and play in an integrated left-/right-brain way is universally evident, and the technical innovations of the day most often coincide with parallel developments in aesthetics (Greenberg, 2008, p 5.).

Creative coding is a branch of computer programming where the end goal isn’t to create something functional but something expressive (Wikipedia contributors, 2021). Thus, creative coding is an example of slow technology (Hallnäs, Melin, Redström, 2002). It has a “strong focus on aesthetics and reflective use rather than on basic efficiency and practical functionality” (Hallnäs et al., 2002).

Digital media artist Adam Ferris (Skidmore, 2014) turns computer programming into art (figure 6). Another example is Zach Lieberman (Joel, 2019), artist and educator based in New York City. He creates artwork (figure 7) with code, and focuses on building experimental animation tools. This work builds on Lieberman’s and Ferris’s way of developing colours and deformation of patterns and images through creative coding. Additionally, Lieberman’s ideas about movement and animation and how that can trigger an emotional response is important in relation to this work, since it explores an expression that depends on the viewers’ response.

Figure 6, Crystal Display, Adam Ferris (Ferris, 2013).
A series of images create through custom software that emulates crystal growth patterns.

Figure 7, Zach Lieberman Instagram feed (Lieberman, 2021).
2.2.5 Motive

Textiles are still considered physical materials and virtual spaces are still somewhat abstract notions where work from textile designers are missing. This work is something that exists in this new space that is growing rapidly in our everyday environment. But where the range of different visual expressions could be greater.

From a sustainability perspective, one future road for the textile industry could be to let the craft exist in the expanding world of virtuality. Lars Hallnäs talks about not doing business as usual as a way of relating to sustainability within a design program. As a designer, one has a responsibility not to be wasteful in the process of creating. This work, therefore, stresses textiles’ virtual presence. It does not propose to replace soft matter in everyday life, but it proposes to help replace the constant strive for new things and contribute to a change in consumer behaviour in the direction of experiences instead of products. Raising the value of digital materiality could change the view of things, matter and how we consume. Addressed by Persson (2013), using a digital world to address design problems there are possibilities to question and develop new physical expressions and experiences.

Contrary to the textile and fashion field, other design fields such as industrial design and architecture have been using 3D software for many years. The fashion and textile fields reasons for the slow adaptation into 3D tools in the design process could be explained in the available 3D software’s poor quality and bad accuracy of the simulation of materials. Software has traditionally been adjusted to materials used in architecture (McQuilian, 2020). This is changing with software as CLO (CLO Virtual Fashion LLC, 2021) and updated cloth physics simulation tools in general.

In the same way as industrialization and the jacquard loom changed the way we valued and produced textiles, digital experiences and materiality is changing the way we understand and value textiles (Redström et al., 2010). To understand digital tools one also must value their outcome in its current state, not trying to translate it to something that it is not, as a knit, a weave or other traditional textile technique. But to regard it as something new, something that is not defined by its materiality and technique.

What this work aims to build on in previous mentioned references is the aesthetical impact of digital tools and technology used in the design process and a digital materiality. Further, the important notion of how chosen tool or variables feed the outcome. Furthermore, placing this in relation to textile design, the aim is to explore how that could define digital textiles.

¹Lars Hallnäs, Higher Seminars, open lecture, Swedish School of Textiles, 20201117.
2.3 Design program

Assume that a textile is defined by [X], instead of its materiality and technique. Thus, all experimentations within this design program is an exploration of [X].

What does that mean? It means looking for a sensation, a feeling of a textile expression in the interface of the software. It means applying the knowledge of textiles into the virtual world. The software helps the designer to dive into a deeper type of complexity with scale, shape and colours. The knowledge of textiles and fabrics is highly important to be able to relate and induce that feeling.

McQuillan (2020) stresses the tacit knowledge in digital contexts as it helps to anchor the practice. Digital textiles are our lived experiences, our references and our imagination in combination with the visual experience.

When creating a digital textile there is a new set of roles, that is completely up to the designer to set. It has another kind of materiality that is forever changeable, the materiality of immateriality of digital technology. Translating textile thinking into this world is a matter of translating our visual knowledge and feelings of a textile material rather than how it is made. Although there are similarities between design thinking and software. The basics in coding includes sequences, iteration, selections and recursion (figure 8). These are all notions that also occur in a design process. In basic code the process of iterations and recursion is a repeated execution described as loops. This could further be compared to loops in textile construction, weave patterns and the connection with threads in for example a weave (Boyd, 2013). As in textiles, software is also built of a small scale structure that creates a greater whole. Boyd describes the similarities between software and weaving on a metaphorical level (figure 9). This work sees these metaphors and ideas as a way of introducing and understanding the process and the tools of creating digital textiles.

![Diagram of design program](image)

The Software Weaving Metaphor

<table>
<thead>
<tr>
<th>Text</th>
<th>Equivalents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loom</td>
<td>Operating System</td>
</tr>
<tr>
<td>Fibers, Yarns, Threads</td>
<td>Processor Execution Threads</td>
</tr>
<tr>
<td>Stitch Patterns</td>
<td>Basic Code Patterns</td>
</tr>
<tr>
<td>Knots</td>
<td>Loops</td>
</tr>
<tr>
<td>Textural Patterns</td>
<td>Function Patterns, Template Methods</td>
</tr>
<tr>
<td>Fabrics, Carpets</td>
<td>Function Results, Global Program States</td>
</tr>
</tbody>
</table>

![Diagram of software metaphors](image)
2.3.1 Digital design tools

There are several choices of software to choose from when creating in a digital environment. Houdini, Rhino, Maya and Autodesk 3d Max are some examples. Marvelous Designer and Clo 3d are software programs directed especially towards creating realistic cloths and digital fashion. These are all commercial licenced, a few of them are available for free for educational purposes. Overall they are able to make somewhat the same things. The difference is interface, availability, compatibility and costs.

Blender is another choice as it is one of the open-source software that is free to use, share and modify as one pleases. It has had significant updates the last couple of years. In previous versions, the knowledge of code languages and programming was highly beneficial to understand the logic in the software. It is now comparable with other paid software in terms of accessibility and user-friendly interfaces. Efficient and new render engines makes it possible to visualize a result almost instantly. As a designer with a background working with both materials and the body, the understanding and logic of 3d thinking is translated into the understanding of the 3d environments. It is not that different from 3d modelling a mesh to draping a fabric around a mannequin creating dress.

In this work, Blender is chosen as software. Firstly because of previous knowledge in the program, secondly for its free access and large community online and thirdly in the context of experimental work it is highly suitable since it is not customized for the textile and fashion industry. Using tools in a not obvious way makes the work more interesting, it opens up for unexpected results and processes.
2.3.2 Painting with pixels: creative coding

An image is built out from a certain amount of pixels depending on its resolution. One pixel has a colour value that can be put into a list of numbers representing its colour and where in the image it is located. By using a sorting algorithm one can rearrange the order of the pixels in the image, consequently editing and changing the images visual appearance. However, not changing the actual data of the image, just making the screen visualize the image in another order. With a pixel sorting algorithm one can choose what, how much and in what direction to sort the pixels. This process can be applied on a bigger scale, as in Anadol’s work (figure 5). An AI is sorting millions and millions of images. Rearranging them in, using their lists of numbers of colour values, to create the simulated data sculptures.

Looking at a weave construction, there is a resemblance to the structure of an image. The semantic use of a square (pixel) representing the connections between the warp and the weft. Depending on the bindings (pixel order) the type of materials (colour values) used, the weave changes. A combination of these two ways of creating materials was combined in a series of weave and print samples (figure 10). Using a pixel sorted image as both the base for the weave pattern and a sublimation print as a surface layer adding colours to the weave. A third layer was added to the piece. An augmented reality filter that once again rearranged the pixels but in a third direction.

Figure 10: Jacquard and print samples
2.3.3 Photogrammetry: Digitalization from physical weave samples

Within this design program, a first try out in using 3d software in the design process was made in the work Mesh materials (2020). Physical weave samples (figure 11) were 3d scanned and run through photogrammetry software. Digital experiments with the UV-mapping and the texture were made (figure 12 figure 13 figure 14). The aim was to investigate and explore expressions and methods through photogrammetry in relation to woven material.

![Physical weave sample](image)

![Photogrammetry process](image)

*Figure 11 Photogrammetry process*
Figure 12 Physical/Digital weave samples orange camo
Physical weave sample: Double jaquard, filament warp and stretch yarn in the weft.

Digital development.

Figure 54: Physical / Digital weave samples: blue yellow
2.3.4 Categorization of surfaces based on visual appearance

During previous experimentation, a few different surface expressions were defined in relation to its tools. These experiments had a base in a plane, a simple 2D grid. The same method was used, adding variables, testing different combinations of modifiers and settings. A categorization of the surface was made; soft, net, and fractal. Adding a particle system to the plane, letting digital threads grow out from the surface, is an additional category (figure 15). This is based on their visual appearance, not how it is build in terms of the applied modifiers. In the sketches, the same image is used as surface colour to make the surface shapes more clear in distinction to each other.
2.4 Idea/Aim

This work starts from a focus on textiles in a virtual world. It is built on new ideas on material thinking, with an emphasis on the divergence of aesthetic expressions. The idea is to reimagine how textiles are designed and made. An assumption is made that a textile is defined by [X], instead of its materiality and technique. Thus, all experimentations within this design program is an exploration of [X].

The aim is to explore textiles in a digital space through computer-generated images and surfaces in 3d software, with a focus on reimagining what a textile is or might become.
3. Method

This design program has a practice-based design research approach. That initially means to work through trial and error in order to assemble examples that demonstrate the potential and possibilities of expression and function of an idea. In the notion of repeating a process, one learns for every time the process is repeated. Small modifications and variations creates an evolution over time within the process (Jones, 1979). The idea of experimentation is to test a concept or a theory. As Koskinen discusses, the aim is to identify relationships between variables that might be interesting in its visual expression (Koskinen, 2012). The base of this work is the experiments and the analysis of the relationship between the chosen variables.

3.1 Form finding through images

This method is divided into two main workflows, where the output from the first one functions as an input to the second part. The input in both processes is an image (Figure 16).

The analysis in the work is made by retracing the method, looping it over and over again. Through the repetition of the methods, patterns are validated and analysed.

Figure 16 Workflows overview. Part 1 and 2.
3.1.1 Creation of images

An image is put through a pixel sorting generator, Bit-Vision, that generates a series of images in a certain expression (figure 17). The program allows users to select their preferred sorting algorithm, sorting criteria (called ‘comparator’ on the app), directional increments, threshold, and magnitude. Bit-vision operates in real time, enable an image to be sorted with different settings applied one after another to create unique effects (Brand, 2016).
3.1.2 Creation of shapes and surfaces

A new image is then combined with a 3D object in Blender, modified in a few steps and then turned into a mesh (figure 18). The same image is used as a variable in the different steps. Depending on the order the modifiers are applied, the shape and surface is changed on the object. There are also several settings in each modifier that affects the outcome. Here the action sequence is described as linear, but it is circular going back and forth through the steps. Evaluating, analysing and rearranging the variables to shape the mesh in a desirable way. The steps and values of the variables are recorded, so it is possible to go back and forth and recreate a sequence with a new starting point.

Figure 18 Workflow Part 2: Shape generation process
3.1.2 Example of method in images

The images are grouped in colour series and to have a structure to work around when developing examples. A series of generated images (Figure 89) are applied on meshes in Blender in 4 steps (A-D).

A: single plane
B: double plane
C: Exaggerate all settings in the modifiers with a negative number and extract the double plane.
D: Exaggerate all settings in the modifiers with a positive number and extract the double plane.

The image informs the shape and surface of the mesh. Starting from a simple plane, a higher resolution in the mesh then the original image makes the pixels resemble a physical weave surface. It is possible to turn the surfaces in any direction crossing through itself creating complexity in the construction. Thresholds in the settings is where the generated shapes gets to complex or exaggerated to understand. The same settings is applied in several colour series.

Figure 19 Starting point in A: single plane, B: double plane

Figure 20 Starting point in:
C: Double plane with exaggerate all settings in the modifiers with a negative number and extract the double plane.
D: Exaggerate all settings in the modifiers with a positive number and extract the double plane.
3.2 Variables

There are three main groups of variables. Images, 3D objects, and de formers. These categories also include sub variables.

3.2.1 Images: colour and motif

Early on in this work, a range of motifs was tested to decide what type of image to use throughout the project. The choice of using an archetypal pattern typology, generic patterns as a base in the images. Mainly for its recognizability and easy reference to the textile field, but also to have a base for colour development and choices. The choice of colours was tested in a sketching workshop where combinations of different hues were compared in groups and to different backgrounds (figure 21). This was carried out on an iPad with a digital pen and the software adobe fresco. The software Adobe Fresco has a wide range of pencils and brushes that mimics the expression of oil, watercolour and all sorts of different art brushes. The digital pen also has pressure and velocity sensitivity that captures the expression of drawing by hand. Since the overall work only deals with digital materiality, it was natural to use a digital tool in this process as well. A colour scheme (figure 22) based on contrasting colours was set to further develop prints (figure 23).
3.2.2. Meshes

A mesh is a common object type in a 3D scene. Blender comes with a number of mesh shapes that one can start modelling from (Blender Documentation Team, (BDT) 2021). The spheric shaped meshes is discarded and three of the primitive geometrical shapes is chosen for this project. The selection is made based on previous experimentation in Blender, previous results of expression relating to the perception of textiles.

1. Single plane
   The standard plane is a single quad face, which is composed of four vertices, four edges, and one face. It is like a piece of paper lying on a table; it is not a three-dimensional object because it is flat and has no thickness.

2. Double plane
   An extracted single plane, contains at least eight vertices, twelve edges, and six faces, and is a three-dimensional object.

3. Tunnel plane
   An edit of the double plane.

4. Sphere - discarded

5. Ico sphere - discarded
3.2.3 Deformers

Modifiers are automatic operations, algorithms, that affect an object’s geometry in a non-destructive way. With modifiers, one can perform many effects automatically that would otherwise be very time-consuming to do manually and without affecting the base geometry of your object (BDT, 2021).

Modifiers used in the experimentation in blender:

1. **Shader with image texture**, this affects the colour and pattern on the surface.

2. **Displacement** with an image-based texture. The intensity of the texture and the colour data from the image decides the deformation of the grid.

3. **Subdivision surface** makes a high definition grid that enhances or smoothens the shape depending on settings.

4. **Screw modifier** creates a helix-like shape to a mesh.

5. **Simple deform** applies a twist, bend, taper or a stretch to the mesh. Deformation is specified by rotation or scaling.

6. **Wireframe** transforms a mesh into a wireframe by iterating over its faces, collecting all edges and turning those edges into four-sided polygons.
4. Development

4.1 Phase 1: Finding structure in the method

The first experiments with different generic textile prints was conducted in a quite open and unstructured manner. Different variations in contrast in colours, scale and propositions were tried out. The images were applied on different meshes in blender and evaluated and analysed through the experimentation (fig 24 - 46).

In figure 24 - 34, the transition in colours that the watercolour pencil creates in the images makes an expressive gradient in the shape development. In figure 32, the contrast in printed and solid coloured segments in the image and the gradient from top to bottom in colour when stretched out in the z-axis creates depth and an interesting mesh shape.

Further, experiments to develop the shapes were made (fig 33-46). Continually in an intuitive manner, looping the method, applying images and trying different settings in the displacement settings. The example with a plaid print base and a double plane as base (figure 46) was interesting in how the displacement modifier made the mesh turn inside out in a certain interval in the settings. Making the image appear from the top and bottom perspective and stretched out in the sides. Figure 48-61 is all additional experiments and developments with the same base mesh as in figure 46.

Figure 62 - 63 is experiments with a sphere mesh and a modular square structure as a base mesh. These experiments are interesting, but was not included for further development in this work. They have another type of scale that did not correspond with the rest of the experiments.

To summarize the experiments, an overview document as been present throughout the work with a selection of the generated shapes group based on surface shader (Figure 63).
4.1.1 Image in relation to shape experiments

Figure 24 Image in relation to shape experiment.
Figure 25 Image in relation to shape experiment
Figure 26 Image in relation to shape experiment
Figure 27 Image in relation to shape experiment
Figure 29 Image in relation to shape experiment.
BASE: DUALPLANE WITH CONNECTED SIDES
SHADER: SAME AS IN TEXTURE
MODIFIERS:
- DISPLACEMENT WITH IMAGE TEXTURE
- SUBDIVISION SURFACES

Figure 30 image experiment
Figure 32 image experiment
BASE: DOUBLE PLANES WITH CONNECTED SIDES
SHADER: SAME AS IN TEXTURE
MODIFIERS: DISPLACEMENT WITH IMAGE TEXTURE
SUBDIVISION SURFACES

Figure 33 Image Experiment
BASE:
DUMBLE PLANE WITH CONNECTED SIDES
SHADER:
SAME AS IN TEXTURE
MODIFIERS:
DISPLACEMENT WITH IMAGE TEXTURE
SUBLIMATION SURFACES

Comment:
BASE:
DOUBLE PLANE WITH CONNECTED SIDES

SHADER:
SAME AS IN TEXTURE

MODIFIERS:
DISPLACEMENT WITH IMAGE TEXTURE
SUBDIVISION SURFACES

Figure 35 image experiment
BASE:
DUMBLE PLANE WITH CONNECTED SIDES

SHADER:
SAME AS IN TEXTURE

MODIFIERS:
DISPLACEMENT WITH IMAGE TEXTURE

SUBDIVISION SURFACES

Figure 36 image experiment
Figure 37: Image experiment

- **BASE:** DUSK LE FLANE WITH CONNECTED SIDES
- **SHADER:** SAME AS IN TEXTURE
- **MODIFIERS:** DISPLACEMENT WITH IMAGE TEXTURE
- **SUBDIVISION SURFACES**
BASE: PLAN
SHADER: SAME AS IN TEXTURE
MODIFIERS: DISPLACEMENT WITH IMAGE TEXTURE
SUBDIVISION SURFACES

Figure 39 image experiment
BASE: PLANE
SHADER: SAME AS IN TEXTURE
MODIFIERS: DISPLACEMENT WITH IMAGE TEXTURE
SUBDIVISION SURFACES

Figure 41: Image experiment
Figure 42 image experiment
BASE: PLANE
SHADER: SAME AS IN TEXTURE
MODIFIERS: DISPLACEMENT WITH IMAGE TEXTURE
SUBDIVISION SURFACES

Figure 43 image experiment
Figure 44: Image experiment

BASE: PLANE
SHADER: SAME AS IN TEXTURE
MODIFIERS:
- DISPLACEMENT WITH IMAGE TEXTURE
- SUBDIVISION SURFACES
Figure 45: Image experiment

BASE:
PLANE
SHADES:
SAME AS IN TEXTURE
MODIFIERS:
DISPLACEMENT WITH IMAGE TEXTURE
SUBDIVISION SURFACES
Figure 46 image experiment.
4.1.2 Individual shape experiments

Figure 47: Shape sketches displacement modifier, based on previous experiments (Figure 46).
Figure 49 Shape development, further tests with the additional modifiers on figure 46.
Figure 50: Lightning development, further tests with the different light sources on figure 46.
Figure 51: Further developments, wireframe modifier and lights sketches.
Figure 52: Surface sketches, transparency and lights.
Figure S3 Shape and shader sketches with light
Figure 34: Shader and particle sketch.
Figure 55 Blue plaid image shape sketches: UV mapping, shader transparency, subdivisions.
Figure 56 UV-mapping sketches: the image changes the shape when applied differently through the UV-mapping.
Figure 57: Gravitation sketch. Gravitation is added for a short moment, the mesh collapses and creates a fabric-like expression.
Figure 5.6 Surface image in relation to shape
Figure S9 Surface image in relation to shape
4.1.3 Experiment overview
4.2 Phase 2: Design examples development

In phase 2, a decision to narrow down the image motif to check patterns were made. Based on the relevance and long history of this type of motif have in the context of textiles. Tartan patterns are old, as long back as 1200 BC there are historical observations that includes the description of Celtic clothes with their stripe design and vivid colours. The pattern is recognized by its characteristic check pattern with blocks of colours crossing each other and creating depth in the woven fabric (Scottish Tartans Authority, n.d).

Historically, the colours have been decided depending on available yarn qualities and dye techniques. Usually only a few colours were used, but by mixing them in a weave one could make patterns with a wide range of hues and shades. This is similar to what is happening when dragging an image through the pixel sorting tool (figure 17). The algorithm develops the shades and prints similarly as the visual effect that appears when crossing threads of different colours in a weave.

A look back in the process was also made to find a structure for further collection development. The first colour sketch was used further find a group composition (figure 64). An assessment of the composition of a group was made and additional print images that would correspond with the colour scheme was added (figure 65).

Figure 64 First line up sketch.
Figure 65 Colour series to use as a structure for the group development.
4.2.1 Example 1: White swirl

The White example is a developing from earlier sketches (figure 46, figure 54) and has a tunnel plane as base mesh. This was the first one that was finished and exhibited on the Greenhouse furniture fair 2021, which this year was digital. An image from the blue plaid image series is the image texture for the shape development (figure 66). A range of other image shaders were tried out and an image from the white plaid series (figure 69) was chosen to correspond with the blue background that were set for the exhibition. A hairy surface, digital threads was added to the top and bottom of the base mesh, wish in its transformed shape ends up inside.
Figure 67 Shape development

The surface generated through the blue plaid image got a pleated like expression because of the many shades and gradients in the used image. This is also used further design examples.
Figure 68: Surface shader colour exploration in relation to background and shape.

A range of different surface shaders was tried out to see if another image would enhance the expression of the shape.
For example 1, a white check pattern was chosen based on the blue background that was set for the exhibition on the Furniture fair.
Figure 70: Further image explorations with plaid patterns.
Figure 71: Further image explorations with plasts
Five still images and two animations was chosen for the Greenhouse furniture fair (figure 72, Figure 73). Additional sketches was made of the piece, adding a rotation in its transformation phase (figure 74) and an exploration of backgrounds and placement, a grey white background was chosen for further development (top right corner figure 75).

Figure 72 Furniture fair exhibition images.
Figure 73: Stills from animations, Transformation and inside view.
Figure 74 Rotation sketches.
Figure 75 Rotation, background and placement sketches
4.2.2 Example 2: Sheer check

Figure 76: Blue plaid
The images are grouped in colour series to have a structure to work around when developing examples. Example 2 is developed from the blue image series. A series of generated images (figure 76) are applied on meshes in Blender in 4 steps (A-D).

A: Single plane.
B: Double plane.
C: Exaggerate all settings in the modifiers with a positive number and extract the double plane.
D: Exaggerate all settings in the modifiers with a negative number and extract the double plane.

In this experiment, the last step D was chosen. The totally white surface meant that the coloured parts of the image was hiding inside. To make them visible, a transparency test was made (figure 78). A few surface shaders was tried out (figure 81) and an image from the orange image series (figure 100) was in the end used because of the group composition. A lower stage in the transformation settings was also chosen for the end piece (figure 82).
Figure 78 Transparency tests

BASE: DUMMY PLANE
SHADER: SAME AS IN TEXTURE
MODIFIERS: DISPLACEMENT WITH IMAGE TEXTURE
SUBDIVISION SURFACES
Figure 81 Surface shader variations.

Figure 82 Final shape of the piece.
4.2.3 Example 3: Jelly Totem

In this example, two images are used in the development, one as image texture in the displacement modifier and one in the surface shader. A certain amount of gravity was added to the mesh, which made it to collapse. The gravity process was stopped when the mesh got a certain expression (figure 84). Through earlier test with this shape, a conclusion of a bit calmer image was chosen, in terms of colour and print in relation to the mesh (figure 86). A bit of transparency in the surface shader was added to get a more textile felling and a sense of the mesh inside out shape. In figure 87 and figure 88, it is the same piece but with different backgrounds and lightning. Here you can clearly see the importance of the space where the pieces are presented and how it enhances or hides certain properties like the transparency.
Figure 64: A: no-gravity vs B: applied gravity.
Figure 86: Image shader sketches in relation to the mesh shape.
4.2.4 Example 4: Tartan Towers

The following two examples, Tartan towers and Plaid petals, are both a development from below green image series (figure 89) but with another surface shader image, proportion and rotation in the final pieces.
Figure 90: Taitan tower development.
Figure 93: Tartan tower proportion sketch.
Figure 5: Tartan tower surface shader sketches, print in relation to shape and group composition.
4.2.5 Example 5: Plaid Petals

Figure 93: Shape development
Figure 96. Final proportion and rotation settings.
Row 1: Top, side, front view
Row 2: Top, side, front view, mask mood.
Row 3: Side views.
4.2.6 Example 6: Inside out check

Figure 97: Green plates image series.
Figure 98 Inside out development
4.2.7 Example 7: Orange Fuzz
Figure 102 UV-mapping sketch. Base meshes A & B, differences in direction of the UV-mapping makes different results.

Figure 103 Surface material exploration: transparency, surface textures.
4.2.8 Discarded examples

The following two examples from below image series were discarded in a later stage when sketching on the group composition.
BASE:

SHADER:
SAME AS IN TEXTURE

MODIFIERS:
DISPLACEMENT WITH IMAGE TEXTURE
SUBDIVISION SURFACES

Figure 107: Pepe development peach series.
Figure 108 Peach shape development
Figure 109 Peach shape inside views
4.3 Composition development

When designing a group or collection, the balance and contrast within the group is important to get a successful result. In the composition of the collection, contrast and balance in colour, scale, transparency and surface shader in relation to the individual shape and to the group as a whole is considered throughout the process. In figure 110 one can see sketches from the beginning and the end of the process. Through Figure 111 to Figure 116 one can see development off the group over time with the final composition in figure 116 bottom right corner.

Figure 110 First group sketch and final line up.
Figure 112, Group composition surface shader, scale, angles, placement
Figure 115 Background material sketches in relation to placement and surface shader.
Figure 116 Group composition sketches, placement.
5. Result
WHITE SWIRL
ORANGE FUZZ
6. Discussion & Conclusion

A design process is always a design process, it has certain stages one goes through, regardless in which field or what tools or in what medium one’s practice is. As in Boyd’s (2013) previously mentioned comparison of textile and computer structures (figure 8, figure 9). This is important to remember for the understanding of the context of this work. Sometimes we are so busy inside the world of fibres and threads, one gets lost in the processes of the physical, traditions and norms.

The foundation in the work is textile knowledge applied into a digital craft and an idea of the potential of immaterial textiles. The difference between holding a needle or a pencil with a trackpad or a keyboard is not that big. It is a different medium, but the foundation of the work is still a tactile expression. A tactile expression that in a physical context is fairly well-defined, but which in the digital world has potential to expand those definitions. It is an abstraction of what we know and define as textiles into a new craftmanship. One could explain it as the tactile expression is the medium and the computer is the tool, and together they encapsulate the definition of the design program.

The aim was to explore textiles in a digital space through computer-generated images and surfaces in 3D software, with a focus on reimagining what a textile is or might become. Furthermore, as a framing of the design program, the assumption was made that a textile is defined by [X] instead of its materiality and technique. In hindsight, [X] in this context is the tactile expression.

As for all tools, techniques and mediums, one comes to a point in knowing and understanding when one recognizes the generic expressions of the tools. This is when one could start adding variables to play with the outputs’ expression. In relation to Blender, the modifiers and method used, this work demonstrates a certain expression comparable to a certain expression in a textile technique, for example, weaving. The chosen variables (threads, colour, bindings) and tools (type of loom) generates the output. In this work, the image and the specific settings in the software are the variables that set the output.

In the search for [X], and in the analysis of the experiment, it is clear that one of the key properties in the pieces is the setting of transparency. Another notion is movement, either movement of the viewer or the material, but also an inherent motion in the appearance of the finished pieces. To get the tactile feel, it is important to see a contrast of surfaces.

As a more direct contribution to the field, the work explores plaid in a new context. It speculates on the definition of textiles that disregard the current understanding of materiality and textile techniques. By the use of plaid motives in the images, there is an additional visual reference to the traditional textile field that helps the work in the search of [X].

Furthermore, this work demonstrates that generative methods are suitable for creating groups or collections. As pointed out by Smith (2017) textiles are highly structured and internally repetitive, thus highly suitable for generative design methods. The developed method in the work (figure 16) also shows how 3D software can help produce iterations in a fast and effective manner. This leaves more time for artistic development and makes the design process faster than physical sketch methods used in textile design. The software also helps the designer to dive into a different type of complexity with scale and shape and colours. Processes that usually appear linear are ongoing simultaneously.
Putting this work in a similar context as the recent collection from Bærendalga (2020), where the designs are digital and put into a gaming context, could be one way of commercializing the work. This comes back to textiles’ virtual presence, how to contribute to a change in consumer behaviour in the direction of experiences instead of products. Raising the value of digital materiality could change the view of things, matter and how we consume.

Further development of the method would be to add or replace modifiers and try a similar process in another software. From an exhibition point of view, an effective way of displaying the work is through projection. The collection is placed in a physical space to enhance the experience of the materiality and to really let the viewer step into the world of digital textiles.

In relation to sustainability, this work is not using any physical materials or producing waste in a typical sense. But it does contribute to increased use of computer power, electricity and server power. That is probably a new environmental problem that at first glance may seem as a solution for sustainability issues. From that point of view, that is just a reorganization of consumption and impoverishment of our resources in another way. But what the work actually does is “not doing business as usual” as Hallnäs stresses when discussing sustainability (Hallnäs, 2020). That may help to meet shifting perspectives and challenges.

This work demonstrates the potential of working in a digital space with a new kind of craftsmanship. There is very little research in this area of textile design, where technology is used in the design process and how that creates a certain aesthetic, a crossing between traditional craft and complex computer-generated structures. Furthermore, it is hoped that the outcome of this work can contribute not only to a broadening of the definitions of textiles but also in itself contribute or inspire to meet the future needs of digitalization of craft. How can digitization contribute to developing artistic practices that question materiality and offer possible ways to shift the discourse into other dimensions?

On one level, there I see no difference in digital and physical work, just different structures and hierarchies of organization. The difference is in how we understand and experience materiality and how we value immaterial materials.
7. References


https://freight.cargo.site/w/750/6ba83e442fe83343cf68be6ff6d60f4e69ebea7d5f150da56817f8b953d381 Blue_Wang---Soderstrom_Ittala_Web.jpg [2021-03-19].

A collection of words used in both the digital context and the textile field have been saved in a document. Definitions and translations of the words and notions are compared and analysed throughout the work. This is a tool that helps to find a language around the work and is continuously updated and changed.
<table>
<thead>
<tr>
<th>Word</th>
<th>Definition</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D modelling</td>
<td>The process of developing a mathematical representation of any surface of an object in three dimensions via specialized software. The product is called a 3D model. It can be displayed as a two-dimensional image through a process (rendering) or used in a computer simulation of physical phenomena. The model can also be physically created using 3D printing devices. The manual modelling process of preparing geometric data for 3D computer graphics is similar to sculpting.</td>
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<tr>
<td>3d thinking</td>
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<tr>
<td>Algorithms</td>
<td>The problem-solving procedure, algorithm, is commonly used nowadays for the set of rules a machine (and especially a computer) follows to achieve a particular goal. I</td>
<td><a href="https://www.merriam-webster.com/dictionary/algorithm#note-1">https://www.merriam-webster.com/dictionary/algorithm#note-1</a></td>
</tr>
<tr>
<td>Creative coding</td>
<td>A type of computer programming in which the goal is to create something expressive instead of something functional. There are several code libraries that are suitable for this kind of work. Processing is an open-source graphical library and integrated development environment (IDE) built for the Electronic Arts, new media art and visual design communities with the purpose of teaching non-programmers the fundamentals of computer programming in a visual context. OpenFrameworks is another open source toolkit designed for creative coding.</td>
<td>(<a href="https://en.wikipedia.org/wiki/Creative_coding">https://en.wikipedia.org/wiki/Creative_coding</a>).</td>
</tr>
<tr>
<td>Digital</td>
<td>Something that exists as a series of the digits 0 and 1. 'Comes from 'digit', which means number - originally 'finger' referring to counting on the fingers. 'Digital' means represented as digit(s), using calculation by numerical methods that involve the Arabic numbers 1-9 and the symbol 0, or by discrete units. According to this definition, anything represented by numbers is digital: my old thermometer is digital because I measure the temperature according to a scale and read it as a digit. However, we normally use the term 'digital' about digital representations implemented on, or by means of, a computer: the digital is also electronic. In an electronic digital system - a computer - the digital representation is binary, as zeroes and ones.&quot;</td>
<td>BRATTETEIG, T. 2010. A Matter of Digital Materiality. Springer London.</td>
</tr>
<tr>
<td>Digital image</td>
<td>raster graphics or bitmap image is a dot matrix data structure that represents a generally rectangular grid of pixels (points of colour)</td>
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<td>Elasticity</td>
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<tr>
<td>Fibre</td>
<td>a thread or a structure or object resembling a thread</td>
<td><a href="https://www.merriam-webster.com/dictionary/fiber">https://www.merriam-webster.com/dictionary/fiber</a></td>
</tr>
<tr>
<td>Haptic</td>
<td>relating to or based on the sense of touch</td>
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<tr>
<td>Intertwined</td>
<td>connect or link (two or more things) closely</td>
<td>Definitions from Oxford Languages</td>
</tr>
<tr>
<td>Matter</td>
<td>Physical substance in general, as distinct from mind and spirit; (in physics) that which occupies space and possesses rest mass, especially as distinct from energy.</td>
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<td>Material preview</td>
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<tr>
<td>Materiality</td>
<td>The quality of being material; having physical existence, the quality of being composed of matter.</td>
<td>Definitions from Oxford Languages</td>
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<td>Modifiers</td>
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<td>Non woven</td>
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<td>Object</td>
<td>Definition</td>
<td>Source</td>
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<tr>
<td><strong>Physical</strong></td>
<td>Relating to things perceived through the senses as opposed to the mind: tangible or concrete.</td>
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<tr>
<td><strong>Projection mapping</strong></td>
<td>Similar to video mapping and spatial augmented reality, it is a projection technique used to turn objects, often irregularly shaped, into a display surface for video projection.</td>
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<tr>
<td><strong>Render</strong></td>
<td>To generate actual viewable images from a 3D model or scene.</td>
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<tr>
<td><strong>Spatial</strong></td>
<td>Connected with space and the position, size, shape, etc. of things in it.</td>
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<tr>
<td><strong>Subsurface</strong></td>
<td>Subdivision Surface (Subsurf) is the tool that subdivides your model at render-time without affecting your mesh at design-time.</td>
<td><a href="https://en.wikibooks.org/wiki/3D_blender_tut/Glossary">Blender 3D: Noob to Pro/Glossary</a></td>
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<td><strong>Surface</strong></td>
<td>Perceptible by touch</td>
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<td><strong>Tangible</strong></td>
<td>Anything that can be touched, felt, or seen.</td>
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<tr>
<td><strong>TEXTILE</strong></td>
<td>A textile is a flexible material consisting of a network of natural or artificial fibres (yarn or thread).</td>
<td><a href="https://en.wikipedia.org/wiki/Textile">https://en.wikipedia.org/wiki/Textile</a></td>
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<tr>
<td><strong>Transfer print</strong></td>
<td>A transfer print is when the paint is vaporised and sublimated into the textile. A digital printer with disperses dyes cartridges prints on a special polymer treated paper. Then the paper and the given material in a heat press. The print evaporates from the paper and transmits into the material.</td>
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<tr>
<td><strong>UV mapping</strong></td>
<td>UV mapping is a technique used to &quot;wrap&quot; a 2D image texture onto a 3D mesh. &quot;U&quot; and &quot;V&quot; are the names of the axes of a plane, since &quot;X&quot;, &quot;Y&quot; and &quot;Z&quot; are used for the coordinates in the 3D space.</td>
<td><a href="https://en.wikibooks.org/wiki/3D_blender_tut/UV_Map_Basics">Blender 3D: Noob to Pro/UV Map Basics</a></td>
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<tr>
<td><strong>Virtual</strong></td>
<td>Not physically existing as such but made by software to appear to do so.</td>
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<tr>
<td><strong>Visual</strong></td>
<td>Something you see</td>
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<tr>
<td><strong>Volume</strong></td>
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<tr>
<td><strong>Weaving</strong></td>
<td>A method of textile production in which two distinct sets of yarns or threads are interlaced at right angles to form a fabric or cloth.</td>
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<td><strong>Abstraction</strong></td>
<td>To be broken down into individual components</td>
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<tr>
<td><strong>Tangible</strong></td>
<td>Tangible means anything which we can touch, feel, and see. So any tangible assets are assets that have physical existence and their physical property, can be touched. Example of Intangible Assets includes: Goodwill, Patent, Brand, Copyright, Trademarks, and Permits: Patent, Brand, Copyright, Trademarks, and Permits, etc.</td>
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<td>Digital</td>
<td>translation</td>
<td>textile</td>
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<tr>
<td>3d modelling</td>
<td>Creating shape in software, sculpting, building meshes.</td>
<td>Draping</td>
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<tr>
<td>Algorithms</td>
<td>A chain of code</td>
<td>A method, a workflow or a tool</td>
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<tr>
<td>Camera</td>
<td>a way of limiting or controlling the view</td>
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<tr>
<td>Code</td>
<td>The designer, the maker, a material</td>
<td></td>
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<tr>
<td>Faces</td>
<td>part of the surface on a 3d object</td>
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<td>Material</td>
<td>surface</td>
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<td>Material preview</td>
<td>View mood without scene lighting that gives a flat expression of the scene.</td>
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<tr>
<td>Modifiers</td>
<td>A sequence of code that changes the appearance, behaviour or relationship of an object.</td>
<td>A tool, a process of changing an object.</td>
</tr>
<tr>
<td>Properties</td>
<td>The panel that lists everything in the workspace</td>
<td>Like a detailed inventory list of a studio.</td>
</tr>
<tr>
<td>Rendering</td>
<td>Producing an image, a JPG or etc of a certain camera view and frame n the timeline.</td>
<td>Photographing the work.</td>
</tr>
<tr>
<td>Roughness</td>
<td>A scale from 0-1. Sets the dullness of a surface material, where 0 is shiny and 1 is dull.</td>
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<td>Solid</td>
<td>nonwoven</td>
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<tr>
<td>Subfaces</td>
<td>resolution</td>
<td>density</td>
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<tr>
<td>Texture</td>
<td>One adds a texture to a mesh. A way to manipulate the meshes surface. To create form.</td>
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<tr>
<td>Transparency</td>
<td>Transparency</td>
<td>the density of a material</td>
</tr>
<tr>
<td>Velocity</td>
<td>part of the physics, forever changeable, an important variable</td>
<td></td>
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<tr>
<td>Vertices</td>
<td>the smallest building parts</td>
<td>The digital representation of a fibre,</td>
</tr>
<tr>
<td>Wireframe mood</td>
<td>A stripped-down view mood where you only see the vertices (fibre) and edges off a mesh</td>
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</table>