

# Virtual Loom, from Historical Fabrics to Interactive 3D Models

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## ABSTRACT

In the field of Cultural Heritage, the documentation of historical fabrics and their weaving techniques, usually lack of a 3D representation. In many cases, it is enough to document such objects in 2D graphics or textual descriptions. However, there are geometries and details of greater complexity that require more complete models to understand the techniques and be able to preserve them over time. In this area, the Virtual Loom tool has been created within the SILKNOW European Project. The demo that we present allows us to show weaving techniques from the 15th to the 19th century in a 3D representation and later we can explore it in different ways. The tool includes a variety of historical weaves, weaving techniques and threads. All this has been created based on the knowledge of experts in historical fabrics, art history and computer graphics.

## CCS CONCEPTS

•Human-centered computing~Visualization~Visualization systems and tools~Visualization toolkits

## KEYWORDS

3D modelling;fabrics;designs;interaction;image analysis.

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## 1 Introduction

Virtual Loom is a tool developed under the H2020 SILKNOW project (Portalés et al. 2018). This software incorporates historical weaving techniques to produce 3D models of fabrics, given an input image of a fabric or a technical drawing. Virtual Loom's graphical user interface has been designed as a wizard that guides the user through the production process of models considering profane users in textile processes and historical weaving techniques. All this has been possible thanks to the close collaboration of experts in computer graphics, art history and ancient textiles.

The current version of Virtual Loom (2019), implements 39 fabrics and 5 traditional weaving techniques. In addition, we have included a "freestyle" weaving technique. This allows the user to experiment with Virtual Loom and opens possibilities to a wider audience, as well as to the creative industries. This freestyle eliminates all historical restrictions on fabric definitions and allows the user to make any combination of techniques, weaves and yarn types. The resulting model can be exported to STL format for printing on a 3D printer.

## 2 State of the Art

Many authors have studied how to represent fabrics through a 3D representation, but there are no works focused on the 3D representation of ancient textiles. (Etmuss et al. 2003) presents a model for the physical simulation of clothing with a performance of 25 fps. on a P4. Another different model proposed by (Jiang and Chen 2005; Cirio et al. 2015) allows to represent fabric at the thread level. There are other models focused on visualization, leaving aside the physical model (Wu and Yuksel 2017). The priority in our development is the representation of historical weaving techniques regardless of how those fabrics can finally form clothing. On the other hand, the generated 3D model must allow interaction and visualization, in real time, in teams that do not have to be specialized in computer graphics, since what is sought is cultural dissemination using Virtual Loom. This fact generates strong requirements in the selection of the 3D structures and in the visualization capabilities.

Nowadays, in the textile industry, there is software for the 3D representation of fabrics. An example is WiseTex (Lomov 2005, 2011). This tool incorporates modules for internal geometry representation, virtual reality visualization, cutting, compaction, etc. Another example is TexGen (2018), where the geometry of textile structures is modelled with a variety of properties: textile mechanics, permeability and compound mechanical behaviour.

These software tools have a similarity to Virtual Loom, as they can create 3D representations for a fabric, based on a design. However, Virtual Loom differs from them from the beginning. While other tools are generally intended to create designs and visualize them in 3D before making fabrics, in Virtual Loom the whole process starts with real fabrics, so we must extract the design and apply yarns, weaves and weaving techniques to visualize them in 3D. In fact, one of the main challenges of Virtual Loom is to extract the design from the images of the historical fabrics or technical drawings. These fabrics can be found in different states of conservation and in different qualities in terms of lighting and resolution.

We can say that the Virtual Loom workflow differs from the rest of the analysed tools, as seen in Figure 1.

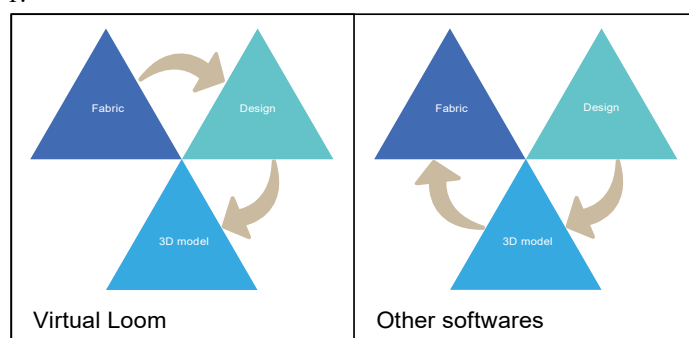
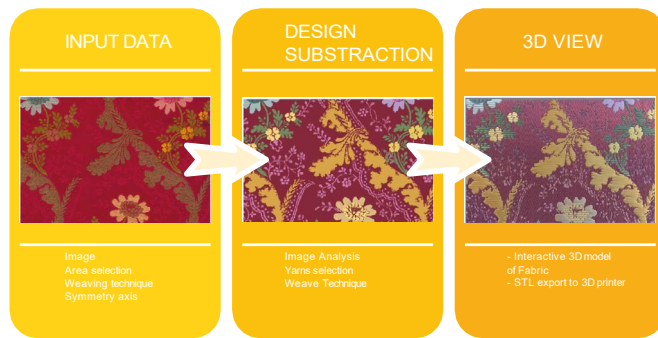


Figure. 1. Overall concept of the Virtual Loom in comparison with other existing tools.

## 3 Design of Virtual Loom

### 3.1 Overview

We will describe the Virtual Loom workflow as shown in Figure 2. The input information for the application is an image together with information related to the fabric (area, symmetries, technique, etc.). Based on this information and through image analysis, the design is extracted. In this phase, you can configure the number of pictorial elements you want to obtain, in addition to the type of technique you want to use in the weaving process. The software allows the selection of different yarns (according to structure, material and colour). With all this, Virtual Loom generates a 3D model of the fabric at the strand level that can be explored from an integrated visualizer in the last step of the wizard. This allows the user to adjust the model resolution, to take captures and to export the model to STL for possible 3D printing.



**Figure 2. Virtual Loom workflow.**

Virtual Loom has been developed using the Unity3D engine. This has allowed us to develop the application for different platforms in parallel. For image processing we have used OpenCV integrated with Unity3D.

### 3.2 Image process

We will explain how image processing is performed in Virtual Loom by following the steps:

- The User selects an image or a part of it using controls that allow selecting an area and correcting the perspective. Also, you can select the aspect of the final image and an axis of symmetry if it exists.
- The image is analysed using OpenCV and it is posterized based on the number of colours that the user has selected.
- Each plain colour of the posterization will be an area of the fabric and will be separated into a black and white image for subsequent processing by the Virtual Loom 3D module.

### 3.3 Yarn level 3D modelling

Virtual Loom has different types of yarns integrated to be able to represent the possible 3D models according to the different techniques implemented. These yarns are mainly, representations of silk, cotton and metallic threads, since they are the most used in historical fabrics between the 15th and 19th centuries that are considered in SILKNOW.

Based on visual characteristics of the yarns we have determined the following parameters to define a type of yarn:

- **Section and thickness:** yarns are generally made up of a group of threads distributed longitudinally within a cylinder. This cylinder can be characterized by its radius (thickness).
- **Composition.** The number of threads in a yarn.
- **Torsion:** In the textile environment, the torsion can be Z or S, depending on the direction of rotation. It can also be more or less depending on the number of laps per unit.
- **Colour:** The user can select the colour from a full RGB palette on silk and cotton. In metallic yarns, the colour of the core is restricted to three possibilities as it was done in the past to give one aspect or another to the metal. The metal band can simulate silver or gold.
- **Detail textures:** These detail textures are normal maps that allow to detail the thread strand without increasing the geometric load on the GPU.
- **Metallicity:** Depending on the visual response of light depending on the surface of the yarn, we can parameterize a metallicity level for each type of thread. For example, cotton has a lower metallicity than silk. While the metallic yarns have a higher value, which allows to appreciate reflections of the surrounding light.
- **Metallic band:** The metallic yarns are constructed from a silk or cotton core on which a metallic thread is wound. This parameter defines at each turn of the metallic thread, what percentage of the core is visible compared to the metallic band that hides it.
- **Torsion of the band:** This parameter defines the number of turns per unit length that the band wraps around the core.

### 3.4 Application workflow

The GUI has been designed as a wizard in order to make the subtraction of designs and the generation of 3D models as simple as possible. Users without any previous knowledge of weaves and weaving techniques can produce 3D representations of fabrics. This defines a sequential workflow, where users must complete each step before advancing to the next one (Figure 3)

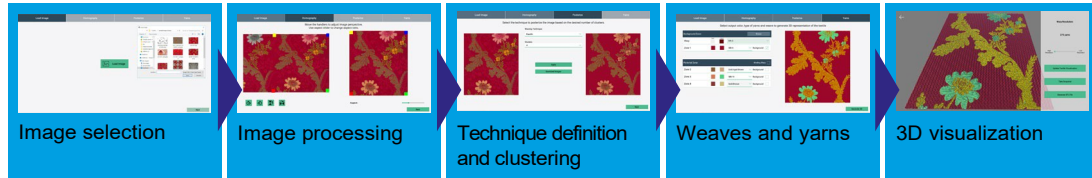


Figure 3. Virtual Loom Wizard.

## 4 RESULTS

These are some of the results that we can obtain from pictures taken from different fabrics. In first place, the fabric corresponds to an espolín with damassé ground clusterized in 12 levels corresponding to the different colours in fabric. Figure 4 shows the clustering process (left), general view (center) and a detail view (right) of the 3d model where can be observed the weaving technique.

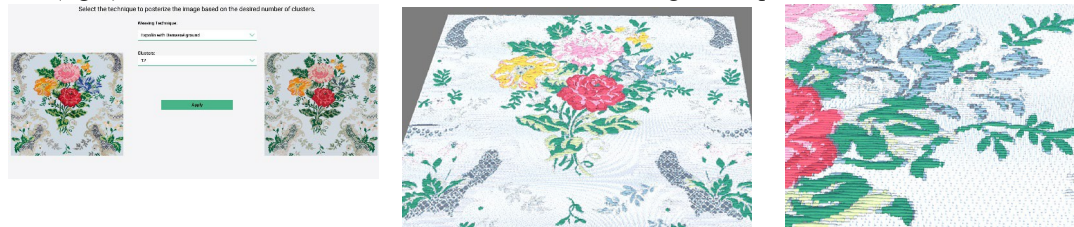


Figure 4. Espolín with damassé ground (from Garín dataset).

The second sample (Figure 5) shows a damaged fabric in the homography process. In this process we activated the vertical mirror option to clone the selected part to complete de full motif(left). In the general view(center) we can appreciate the reconstructed motif. (right) is a detail where weaving technique can be appreciated.



Figure 5. Damassé fabric (from Garín dataset).

During the demo show, the software will be accessible from a laptop running the standalone version to improve performance but could be tested by any user with the online version using his own PC.

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