# Evaluating the Accuracy of Fabric Mechanical Digitization Methods

## - Supplementary Document -

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## I. Fabric Dataset

We packaged the fabric dataset into a single csv file for easy distribution and consumption. Each of the 86 rows is a different fabric. The columns are as follows:

- id
- metadata: composition, density (grams per square meter), structure and thickness (milimeters)
- real Cusick metrics: drape coefficient (DC), fold number (FN), fold height (FH), and drape unevenness (DU)
- digital Cusick metrics for REF
- digital Cusick metrics for KIT-CLO, FC-CLO and TEX-CLO
- digital Cusick metrics for FAB-BW, PHX-BW and TEX-BW
- CLO mechanical parameters for KIT-CLO, FC-CLO and TEX-CLO
- Browzwear mechanical parameters for FAB-BW, PHX-BW and TEX-BW

## II. Sample Preparation and Testing

Capturing the anisotropic properties of fabrics requires testing fabric samples in multiple orientations. We prepare three rectangular samples cut in weft, warp and bias orientations, each measuring $15 \times 6$ cm. Each sample is then mounted on the testing device for automated operation, with one end secured by a fixed clamp and the other by a stepper-driven clamp. As the clamps occupy 2.5 cm at each end, the effective deformable length is 10 cm.

In the tensile test, the sample is incrementally elongated until the tensile force reaches 15 N. During this process, force-elongation measurements are recorded at 0.2 mm intervals, effectively testing loads up to 200 N/m.

In the pear-loop test, the movable clamp gradually advances towards the fixed clamp, inducing a loop in the fabric. During this process, measurements consisting of the distance between the clamps and the silhouette of the fabric sample are recorded at 1 mm intervals. The silhouette is post-processed to extract the height and width of the resulting pear-shaped loop, from which a height-to-width ratio is computed to characterize the loop geometry.

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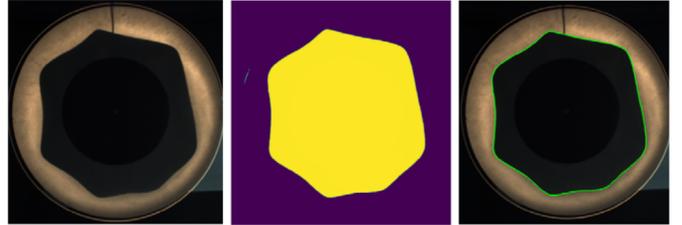


Fig. 1. Estimation of the shadow contour using computer vision. The original photograph (left) undergoes a segmentation procedure (middle) to identify the pixels corresponding to the fabric. Finally, this segmentation is used to generate the contour (right), from which the drape coefficient is estimated.

The tensile test is typically destructive, as it often deforms the material beyond its elastic limit, rendering the sample unusable. Therefore, we first conduct the pear-loop test before proceeding with the tensile test.

## III. Automating the Cusick Drape Test

The traditional method for estimating the shadow area of the Cusick drape test involves manually tracing the casted shadow onto a ring of paper, cutting out the contour, and weighing the cutout. Since the mass density of the paper is known, the area of the shadow can be easily derived from the weight of the cutout. However, this method is prone to human error and is time and material-consuming.

To overcome these limitations, we automated the procedure using computer vision. After careful camera calibration, we capture a photograph of the shadow area and use an image processing algorithm to identify the contour, as shown in Figure 1. By relying on the projected shadow rather than a direct photography of the draped fabric, we avoid potential distortions caused by perspective: the parabolic mirror ensures that light rays emitted from the punctual source become collimated, effectively resulting in an orthographic projection of the silhouette.

### A. Secondary Metrics

Following the work of Carrera-Gallissà et al. [1], we derive three secondary metrics from the estimated projected contours: fold number ($FN$), mean fold height ($FH$), and drape unevenness ($DU$). To do so, we use polar coordinates to represent the contour and identify folds using a peak detection algorithm. Geometrically, folds are modeled as triangles defined by a peak

and two adjacent valleys as vertices. Drape unevenness is the coefficient of variation of the angle between consecutive fold peaks. We refer the reader to [1] for the detailed formulas.

The results of these additional metrics are summarized in Figure 2, which compares all 7 digitization methods with the ground truth for all fabrics in the dataset.

## IV. Cusick Drape Test Intrinsic Errors

We conducted between 2 and 5 Cusick drape tests for each side (front, back) of each physical fabric in the dataset. From these results we derived two errors:

- the *repeatability* error. We computed the per-side average drape coefficient of each fabric by averaging its corresponding drape coefficients, i.e. separating front and back measurements. We then derived a per-side drape coefficient repeatability error for each fabric by taking the average of the difference between each drape coefficient and its corresponding average drape coefficient (front or back). We aggregated all repeatability errors in a single value by taking the mean of all per-side, per-fabric repeatability errors. The resulting repeatability error of the Cusick Drape test is 0.95.
- the *front/back* error. This error is not related to the Cusick drape test itself, but rather to the lack of distinction between the front and back sides of the fabric. We computed the average drape coefficient of each fabric by averaging its corresponding drape coefficients, without separating front and back measurements. We then followed the same approach as for the repeatability error, resulting in a final front/back error of 4.

## V. Digital Cusick Drape Test Setup

### A. CLO Setup

To replicate the Cusick drape test within CLO's CAD software (CLO), we create a 30cm diameter circular fabric piece and define an 18cm diameter interior line to guide node placement. Using the *Pin (Lasso)* tool, we fix all nodes within the interior line, removing it afterwards to prevent a biased remeshing (Figure 3, 2D viewport). We then run the simulation process using the *Fitting (Accurate Fabric)* setting (Figure 3, 3D viewport) and export the draped fabric geometry.

### B. Browzwear Setup

We replicate the Cusick drape test within Browzwear's CAD software (VStitcher) by creating a 30cm diameter circular fabric piece and defining an 18cm interior line to represent the support disc (Figure 4). The presence of this interior line does not affect the meshing and can be kept as a reference throughout the entire procedure. After clicking on *Prepare* to bring the fabric to the 3D viewport, we use the *Styling Tool* to paint the circular area of the support disc and fix the associated nodes by selecting the *Hold* option, ensuring that this region remains frozen throughout the simulation. With the nodes fixed, we run the simulation with the *Auto-Fast Simulation* setting disabled to ensure maximum quality, and export the draped fabric geometry.

### C. Geometry Processing

The geometry exported by either of the above setups is processed in the same manner to obtain the drape coefficient. We project the contour of the geometry onto the floor plane (assuming that gravity acts along the Y axis, the projected contour lies on the XZ plane). This yields a 2D shape that describes the same shadow contour that would be projected onto the paper sheet in a real Cusick drape tester. We then calculate the area of the shape and compute the corresponding drape coefficient.

## VI. Metadata Changes in TEX-CLO, TEX-BW, FC-CLO and PHX-BW

We had to make small adjustments to fabric composition and structure to allow the digitization of some fabrics with metadata-based methods. Specifically:

- Fabric W-07 was supplied without labeling information, which made its composition unknown. In TEX-CLO, TEX-BW and FC-CLO, where there is no "unknown" label, composition was set to 100% cotton. In PHX-BW, composition was set to "unknown".
- Fabrics K-40 and K-41 are Ribs of type 10x3 and 4x3. We used "Rib" in TEX-CLO, TEX-BW and FC-CLO, and "Rib 1×1" in PHX-BW.

## References

[1] E. Carrera-Gallissà, X. Capdevila, and J. Valldeperas, "Evaluating drape shape in woven fabrics," *The Journal of The Textile Institute*, vol. 108, no. 3, pp. 325–336, 2017.
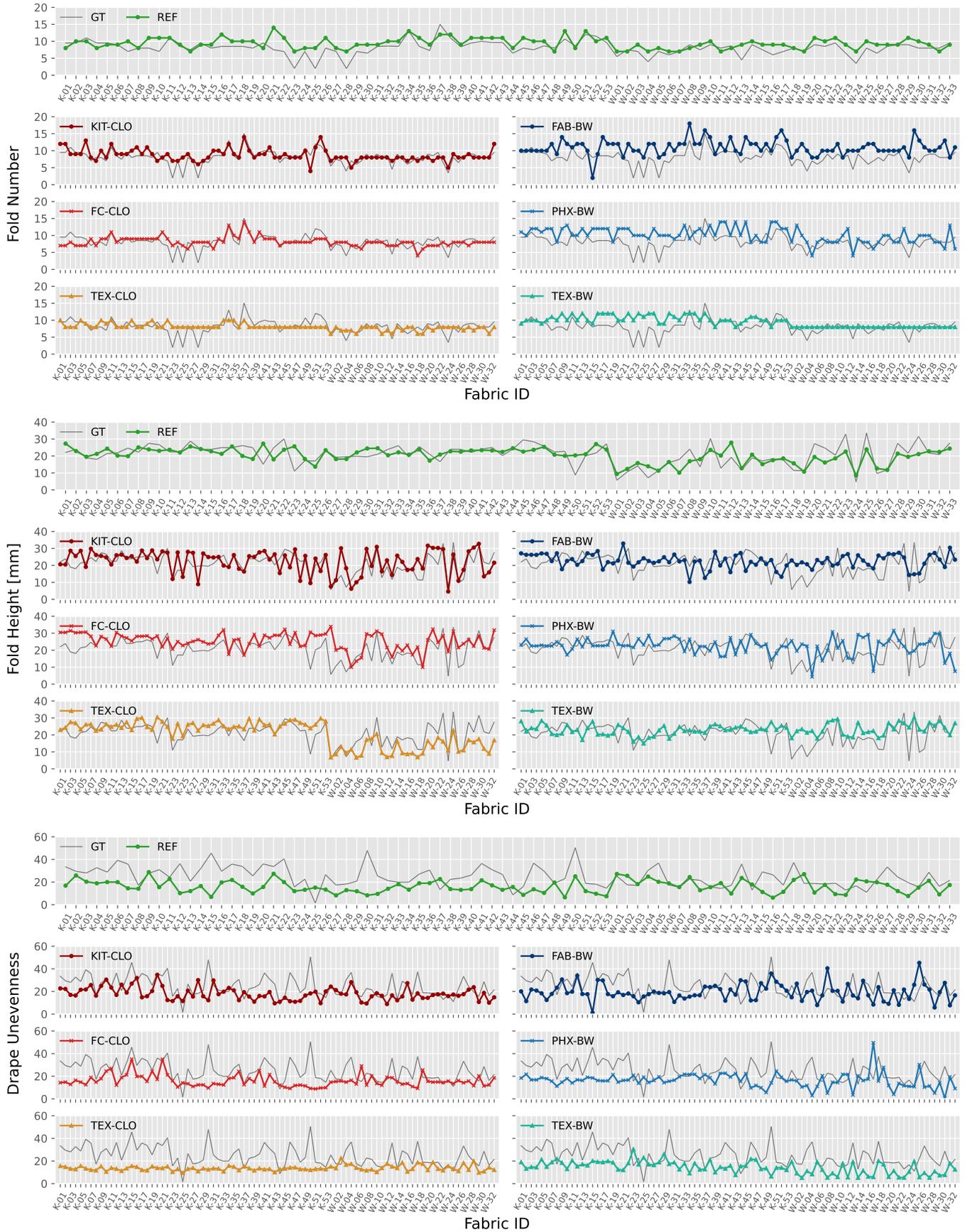
Fig. 2. Comparison of the FN, FH and DU metrics obtained using all 7 digitization methods with the ground truth (GT) for all fabrics in the dataset. The x axis is the fabric ID (K for knits, W for wovens), and the y axis is the corresponding metric. The real (thin, in grey) and its corresponding digital (thick, in color) metrics are plotted for each fabric.
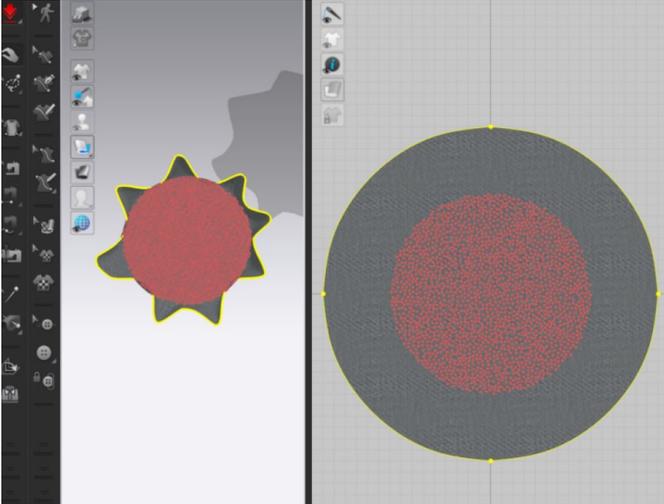
Fig. 3. Digital Cusick drape test setup in CLO. The fixed nodes (in red) emulate the effect of the disks used in the real Cusick drape test.
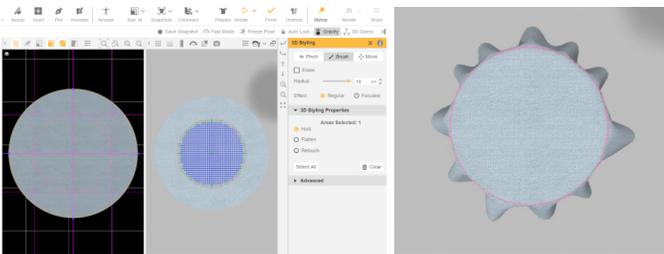


Fig. 4. Digital Cusick drape test setup in Browzwear VStitcher. The fixed nodes (in blue) emulate the effect of the disks used in the real Cusick drape test.