Knitting 4D Garments with Elasticity Controlled for Body Motion

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Introduction

We present a new computational pipeline for designing and fabricating 4D garments as knitwear that considers comfort during body movement. This is achieved by control of elasticity distribution to reduce uncomfortable pressure and unwanted sliding caused by body motion.

Specifically, we develop:

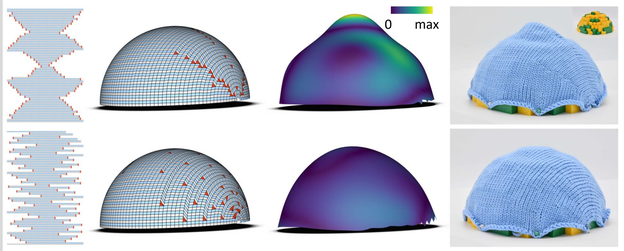
- A graph-based method to generate a knittable stitch mesh that can accurately capture the 3D shape of a surface patch.
- A method to generate machine knitting code for 3D garments with locally varying levels of elasticity, using different SJJ patterns with two yarns
- An iterative algorithm to assign different levels of elasticity in different regions of a garment so that the deformation under body motion can be optimized.

Both large stress (a) and sliding (b) may result in discomfort in perfect-fit garments. 4D knitware (c) minimizes the stress and controls the maximal sliding during body motion.

Method

3D Shaping by Short Rows

Our approach uses only the short-row knitting technique (for efficiency and feasibility on low-cost machines purposes) while controlling the distortion at apexes (end stitches of short-rows).

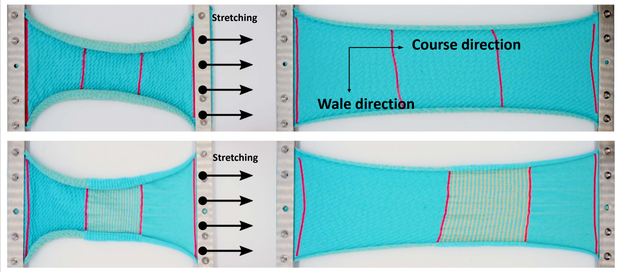


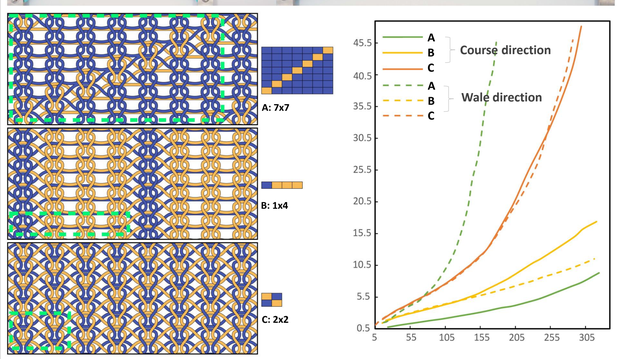
Knitted hemisphere. (red elements: apexes)

Elasticity Control by Single Jersey Jacquard

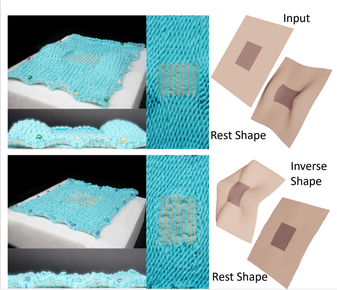
Single Jersey Jacquard (SJJ) is a technique to knit two or more yarns together when moving the carrier horizontally. Specifically, two yarns with different elasticity levels (soft and firm) are employed in our approach.

When altering the arrangement of the two yarns, different elasticities can be formed by changing the periodic pattern.





Stitch Size (Unit: mm) Weight x Height	A 0.125 x 0.0780	B 0.0984 x 0.0680	C 0.0812 x 0.105



Stitch Size Compensation

Elasticity control needs to consider the variation of shrinkage caused by the different stitch sizes presented on the knitted area with virous elasticity. To solve this, we compute the inverse geometry of a 3D surface.

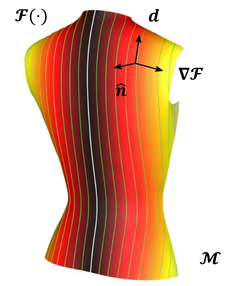
Design and Pipeline

To enable the design and fabrication of 4D knitwear with controlled elasticity distribution for body motion, we

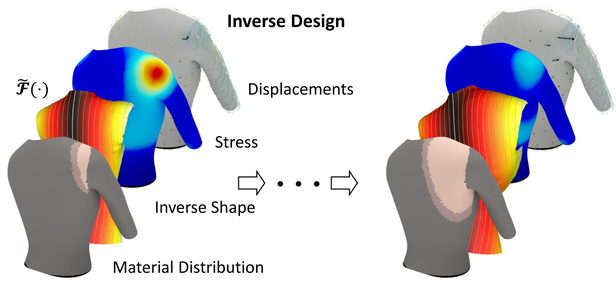
- first precisely fabricate the designed 3D shape by digital knitting, and
- then realize the elasticity variation in different regions by SJJ with two yarns.

Our full pipeline includes:

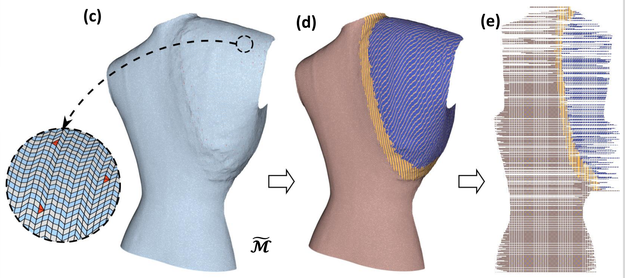
(a) data-driven material tests of SJJ patterns and the geodesic distance-field $\mathcal{F}(\cdot)$ on a garment $\mathcal{M}$ for assigning orientations for knitting stitches and orthotropic material simulation



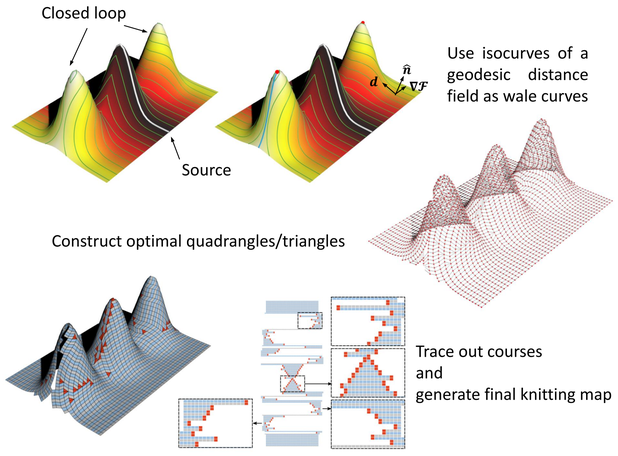
(b) progressive updating of the soft / firm material distribution: apply soft material to high-stress region until the maximal displacement is less than a pre-set threshold



(c) knittable stitch mesh* generated on the inverse geometry $\widetilde{\mathcal{M}}$, **(d)** SJJ patterns assigned on the stitch mesh and **(e)** the resultant knitting map.

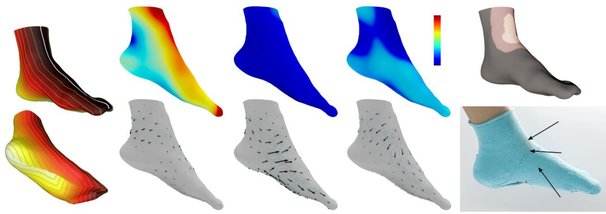


*Generate Knittable Stitch Mesh on surface:



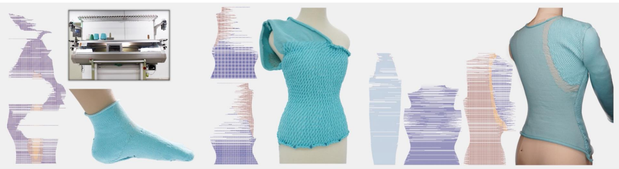
Results

Simulated and fabricated results for sock with elasticity.



Fabricated 3D results with knitting map: short-row based 3D shaping technique.

Fabricated 4D results with knitting map: controlled elasticity distribution.



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