Knitting 4D Garments with Elasticity Controlled for Body Motion

Zishun Liu1,3, Xingjian Han2, Yuchen Zhang3, Xiangjia Chen3, Yu-Kun Lai3, Eugeni L. Doubrovski1, Emily Whiting2, Charlie C.L. Wang5
1Delft University of Technology, 2Boston University, 3Centre for Perceptual and Interactive Intelligence (CPII), 4Cardiff University, 5The University of Manchester

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 SJ 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 knitwear (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).

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 SJ with two yarns.

Our full pipeline includes:

(a) data-driven material tests of SJ 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 \( \mathcal{M} \), (d) SJ patterns assigned on the stitch mesh and (e) the resultant knitting map.