Knitting Skeletons: Computer-Aided Design Tool for Shaping and Patterning of Knitted Garments

Alexandre Kaspar, Liane Makatura and Wojciech Matusik

Motivation

Industrial Knitting

Knitted Results

Infinity scarf with custom lace pattern

Sock with ribbed cuff

Industrial Knitting

- Whole garments from scratch

Industrial Knitting

- Control of individual needles
- Whole garments from scratch

Knitted Garment & Patterns

Many garments are knitted:

- Beanies, scarves
- Gloves, socks and underwear
- Sweaters, sweatpants

Those machine require minimal post-processing (i.e. almost no sewing)












Knitted Garment & Patterns

Those garments have **various types** of surface **patterns**.

These can be fully controlled by industrial knitting machines, and the same is true for the size.

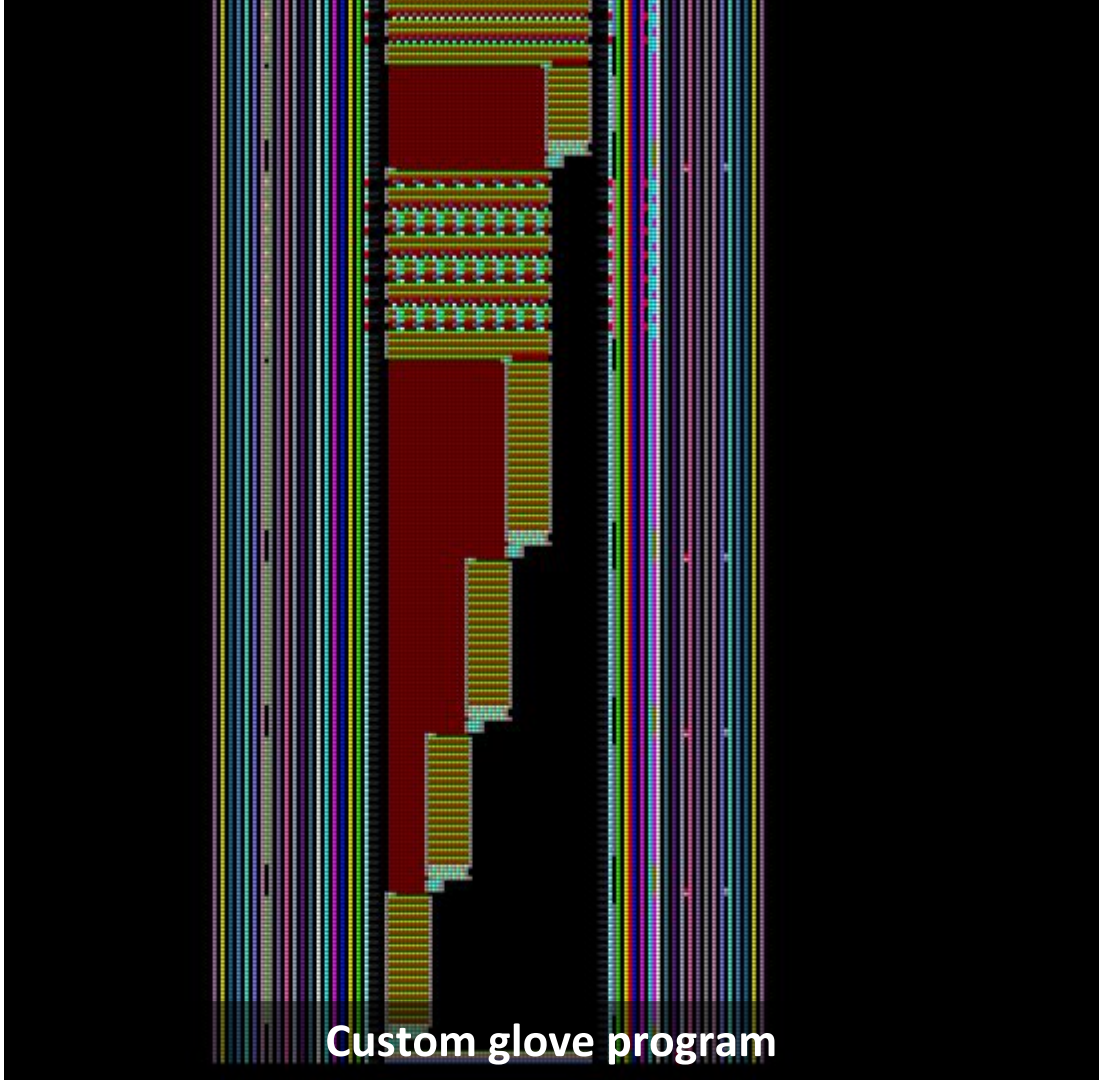
= User customization!

Machine Knitting Programming

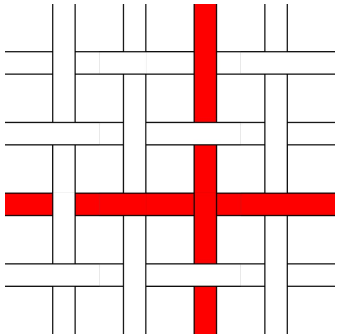
BUT …

Low-level machine code
requires skilled experts

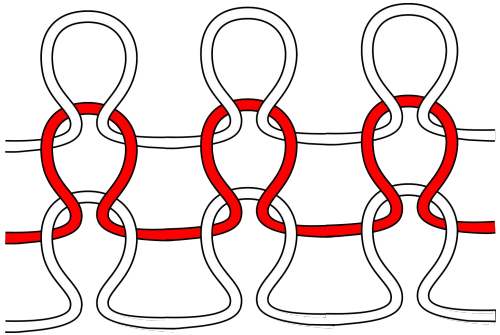
= Knitting masters



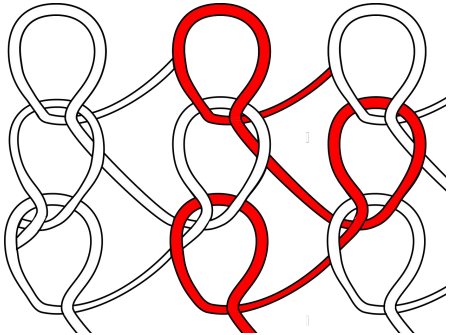
(Brief) Machine Knitting Background



Woven fabric

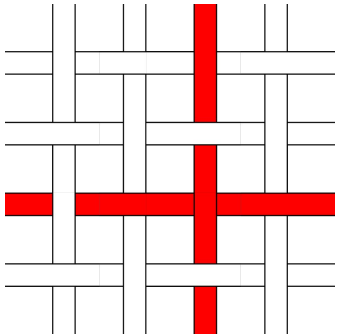


Weft knitted fabric

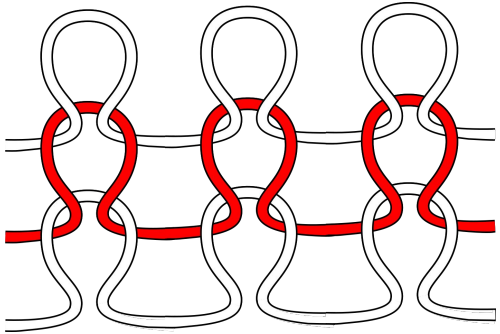


Warp knitted fabric

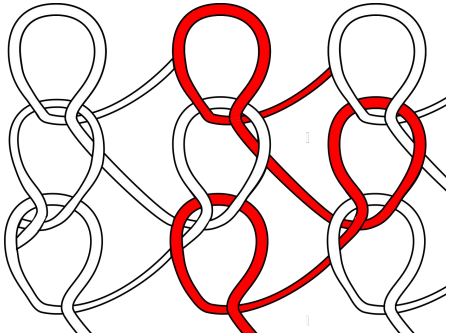
Machine Knitting Terminology



Woven fabric



Weft knitted fabric

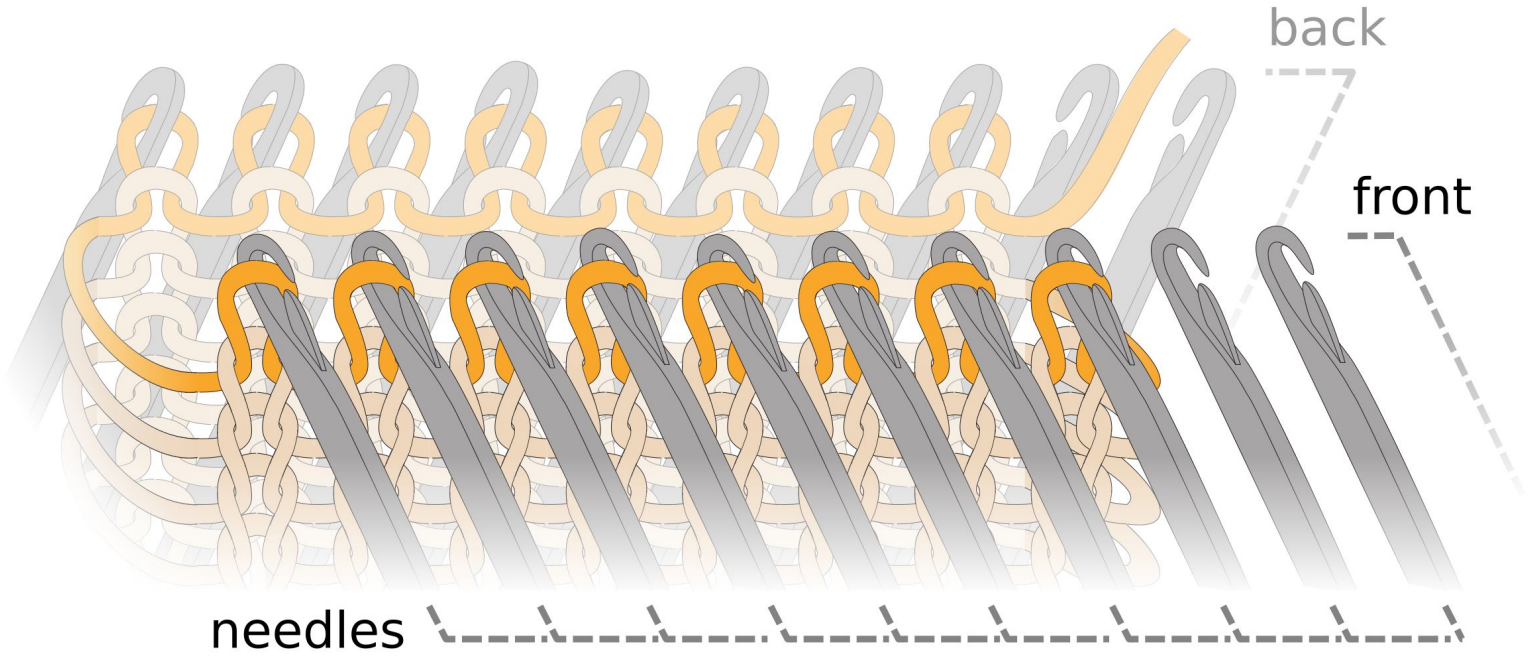


Warp knitted fabric

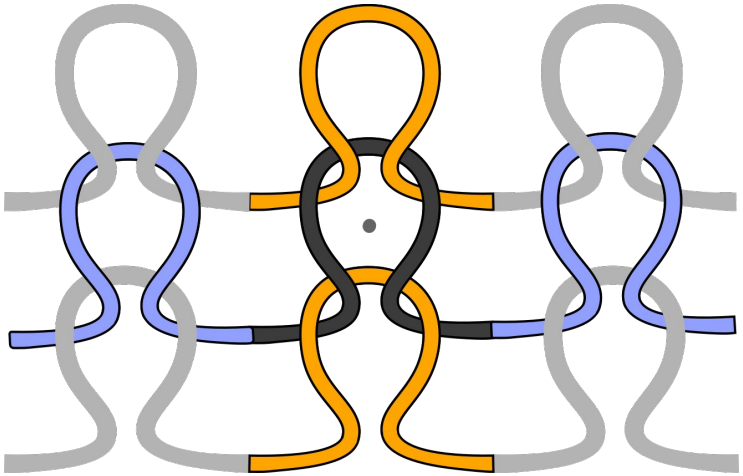
Machine Knitting Terminology

V-bed machine & knitting bed

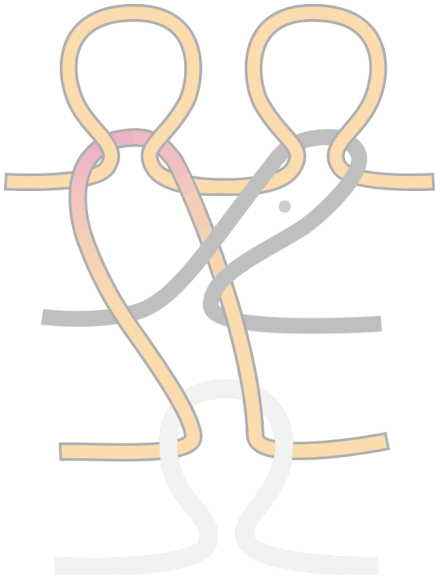
Knitting Beds and Needles



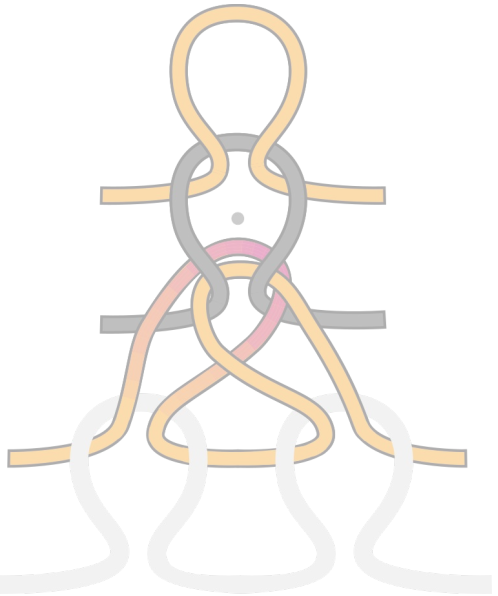
Machine Knitting Terminology



Stitch neighborhood (course, wale)

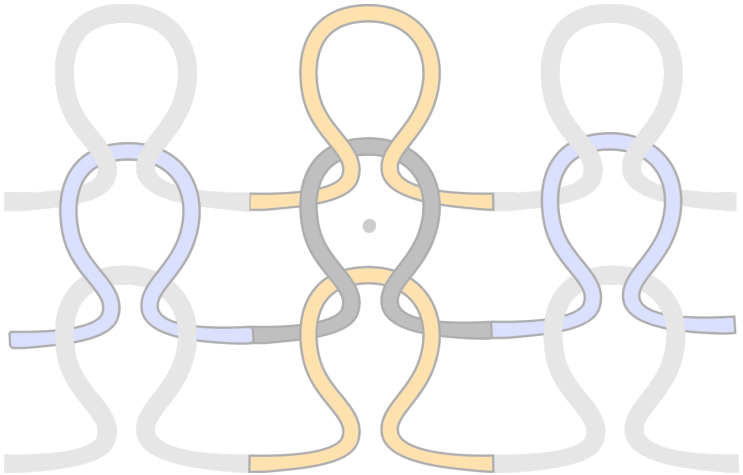


Stitch increase

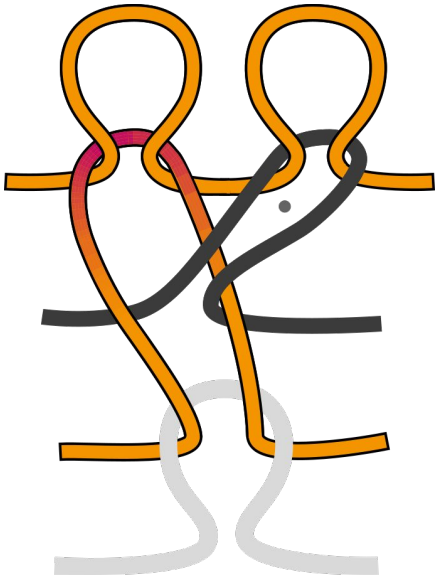


Stitch decrease

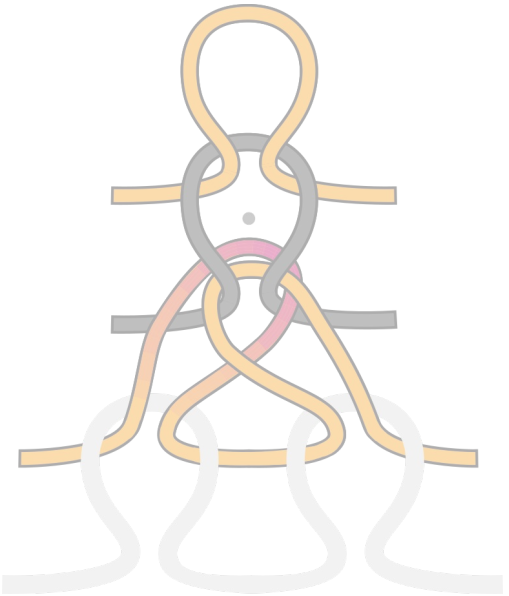
Machine Knitting Terminology



Stitch neighborhood (course, wale)

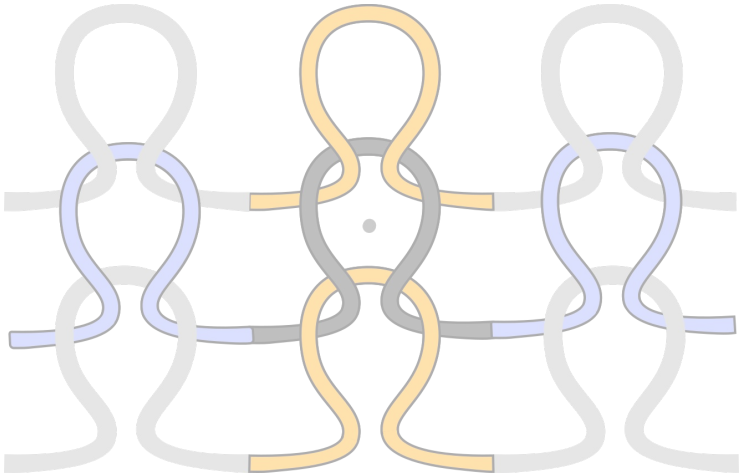


Stitch increase

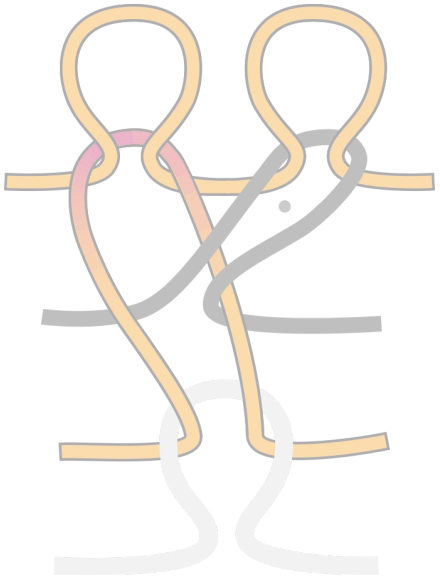


Stitch decrease

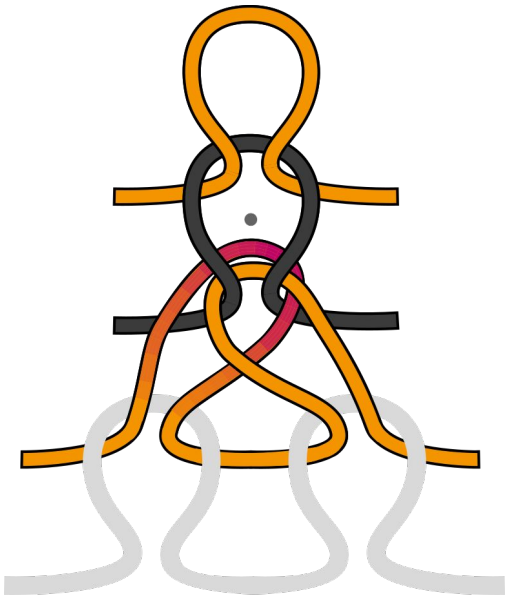
Machine Knitting Terminology



Stitch neighborhood (course, wale)



Stitch increase



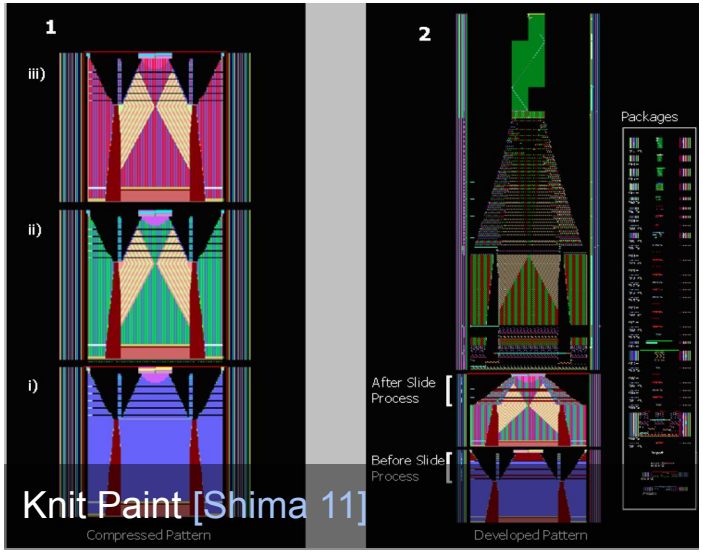
Stitch decrease

Related Workflows for Machine Knitting Design

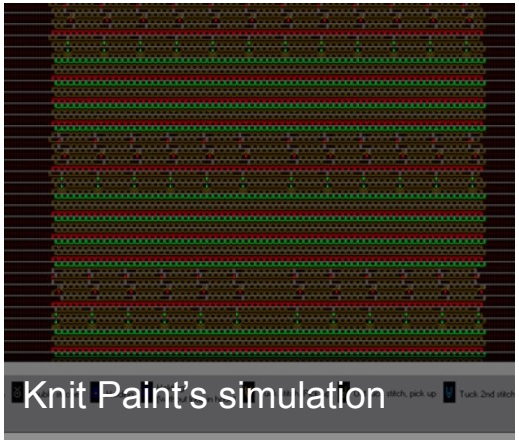
Workflow: Low-Level Knit Programming

+ Full control

- Non-parametric
- Expert complexity
- Not accessible (not open)



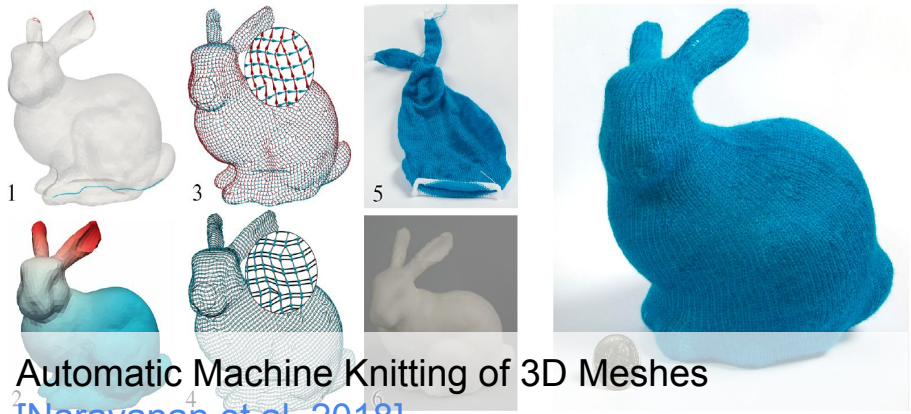
Knit Paint [Shima 11]


Knit Paint's simulation

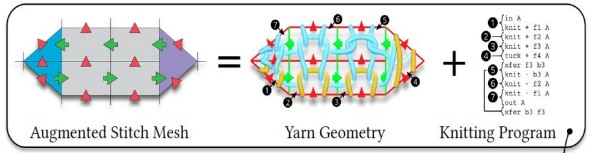
Workflow: Design on 3D Meshes

+ General 3D shapes
+ Preview / feedback

- Non-parametric
- Large complexity



Automatic Machine Knitting of 3D Meshes
[Narayanan et al. 2018]



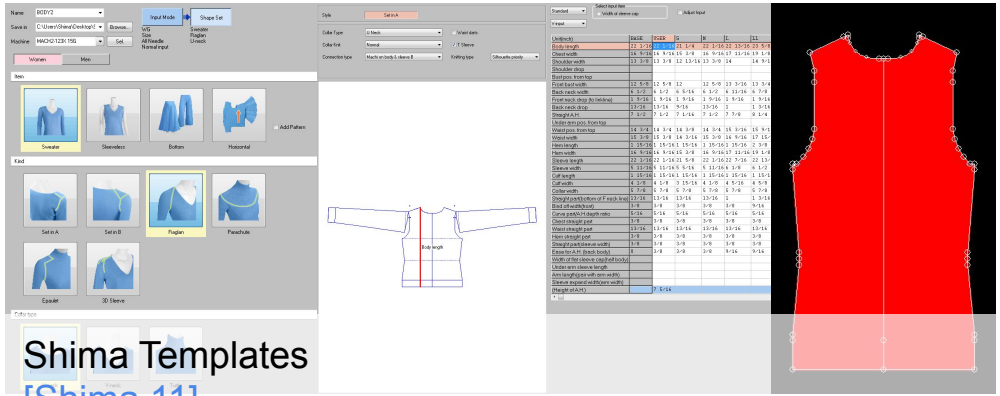
Visual Knitting Machine Programming
[Narayanan, Wu et al. 2019]

Workflow: Primitive-based Design

+ Simpler design space

- Parameterization?
- Customization?
- Composition?

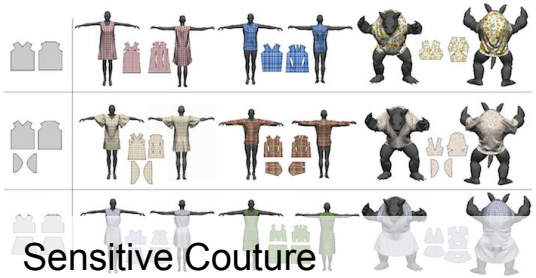
A Compiler for 3D Machine Knitting
[McCann et al. 2016]



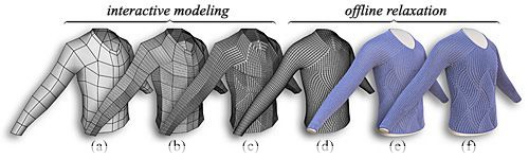
Shima Templates
[Shima 11]

Inspirations

Modeling Garments

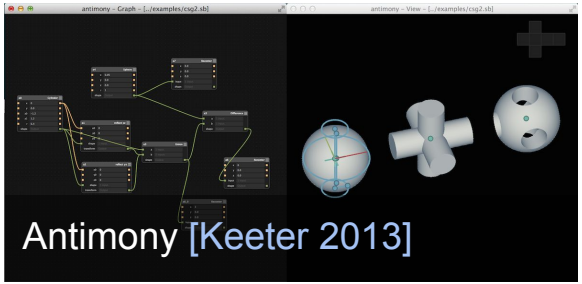


Sensitive Couture
[Umetani et al. 2011]

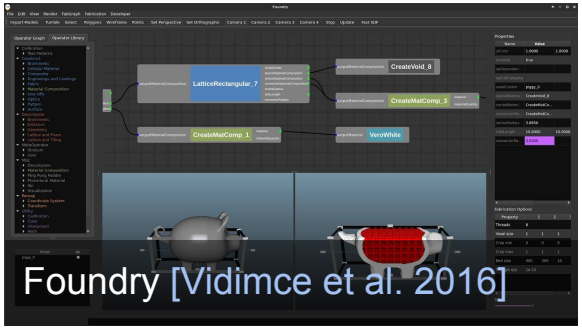


Stitch Meshes
[Yuksel et al. 2011]

Parametric Design

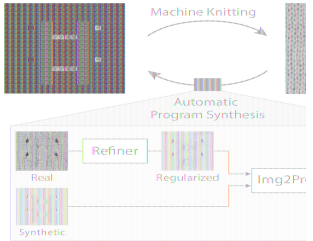


Antimony [Keeter 2013]

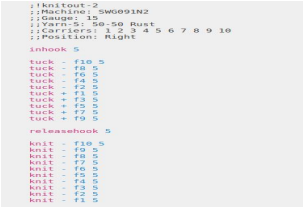


Foundry [Vidimce et al. 2016]

DSL

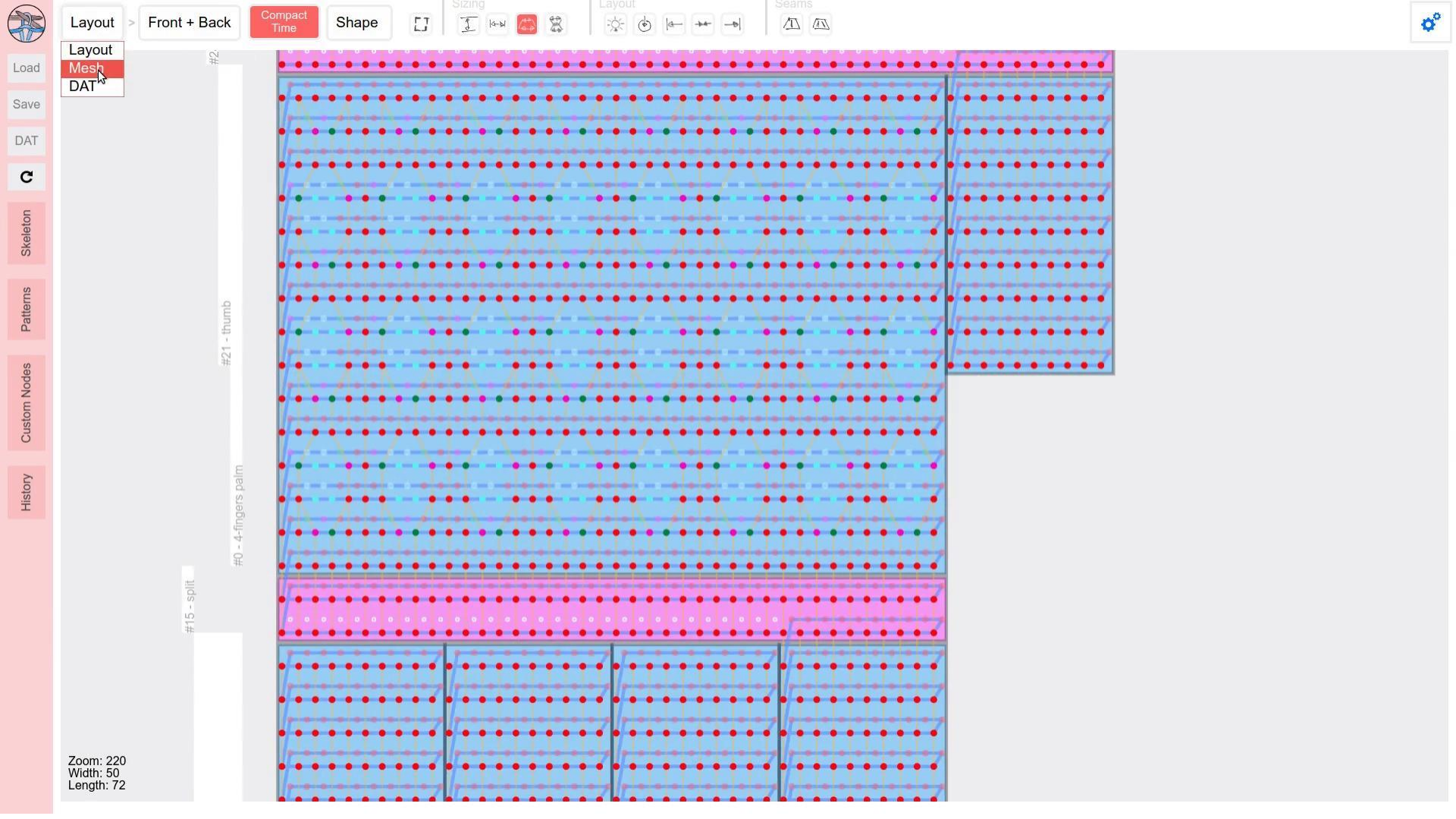


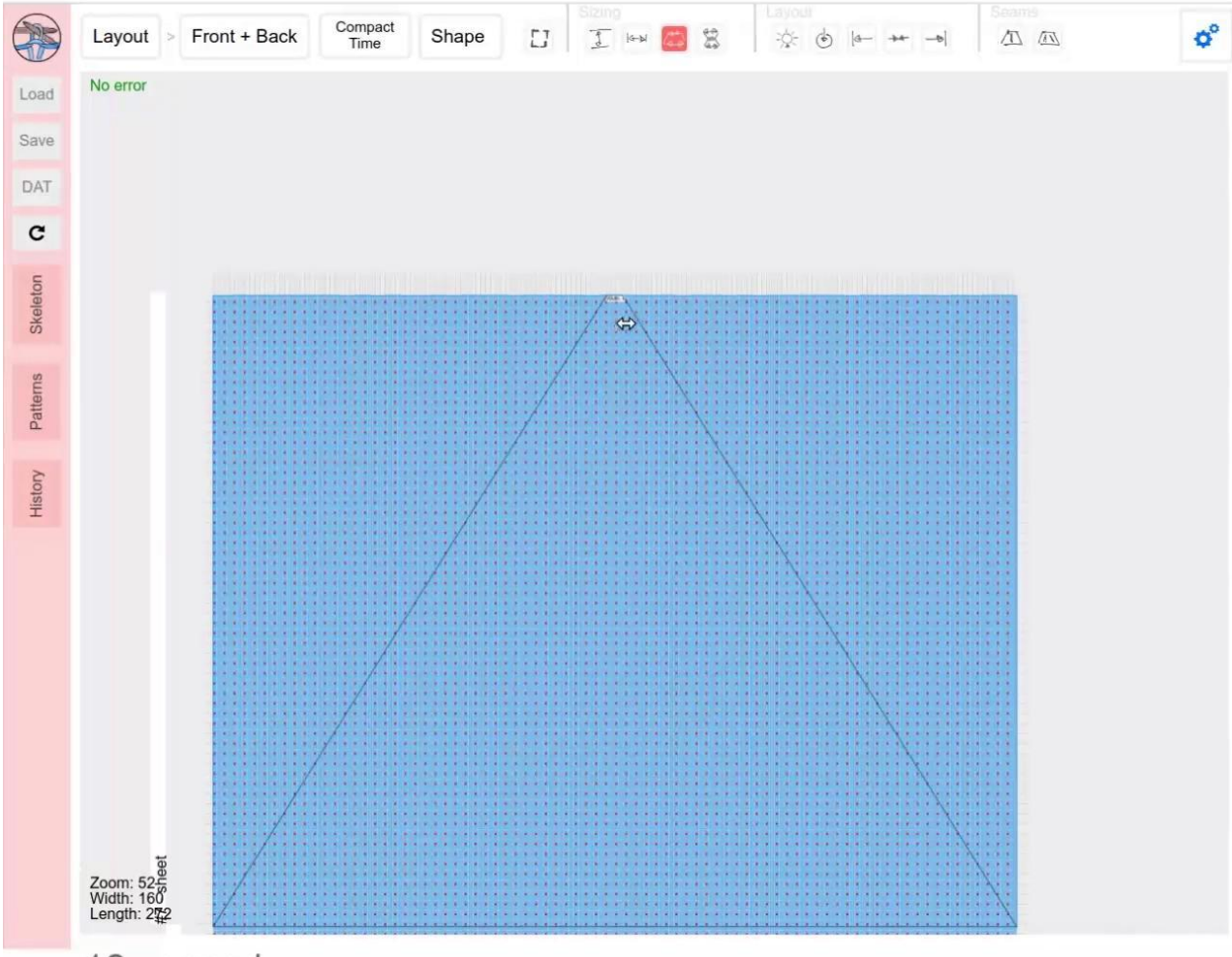
Inverse Knit



Knitout

Our Workflow


Layout
Front + Back
Compact Time
Shape
Sizing
Layout
Seams
Layout
Mesh
DAT
Load
Save
DAT
Skeleton
Patterns
Custom Nodes
History
#21 - thumb
#0 - 4-fingers palm
#15 - split
Zoom: 220
Width: 50
Length: 72


Layout
Front + Back
Compact Time
Shape
Sizing
Layout
Seams
No error
Load
Save
DAT
Skeleton
Patterns
History
Zoom: 52
Width: 160
Length: 272
Sheet #2

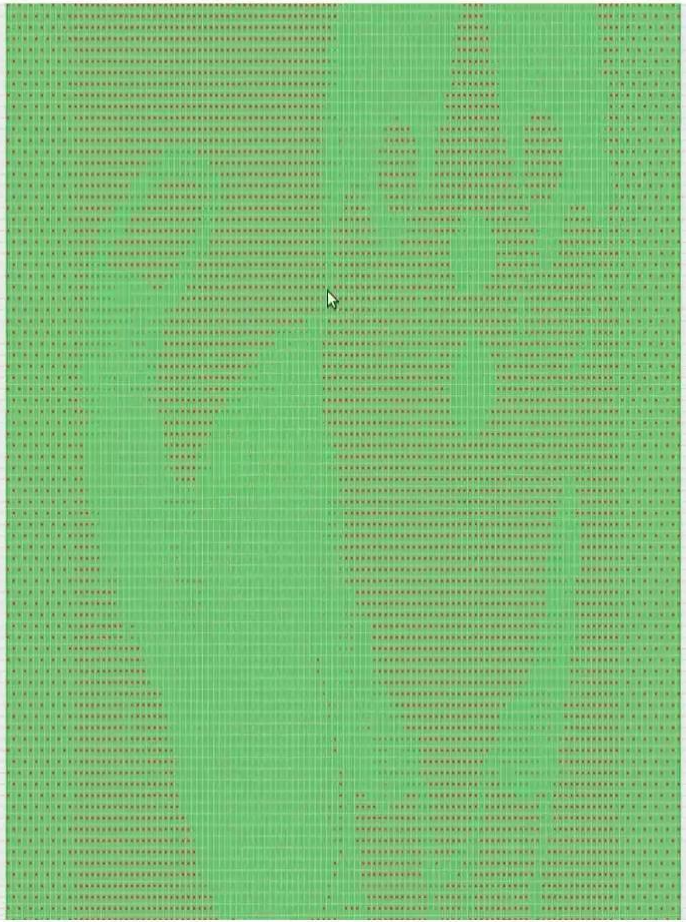
10x speed

Layout > Front + Back | Compact Time | Shape

Sizing | Layout | Seams

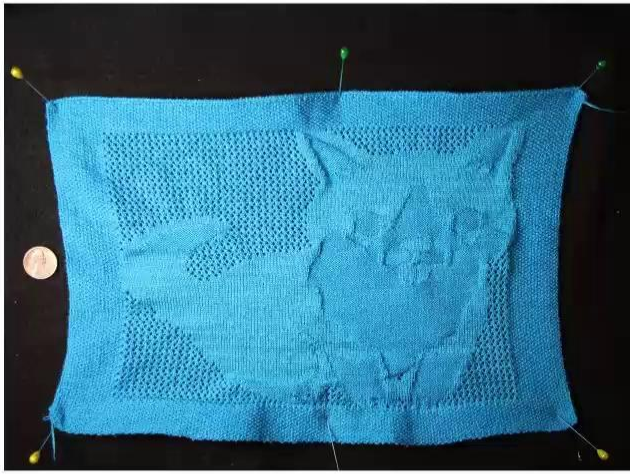
Load
Save
DAT
Skeleton
Patterns
History

No error

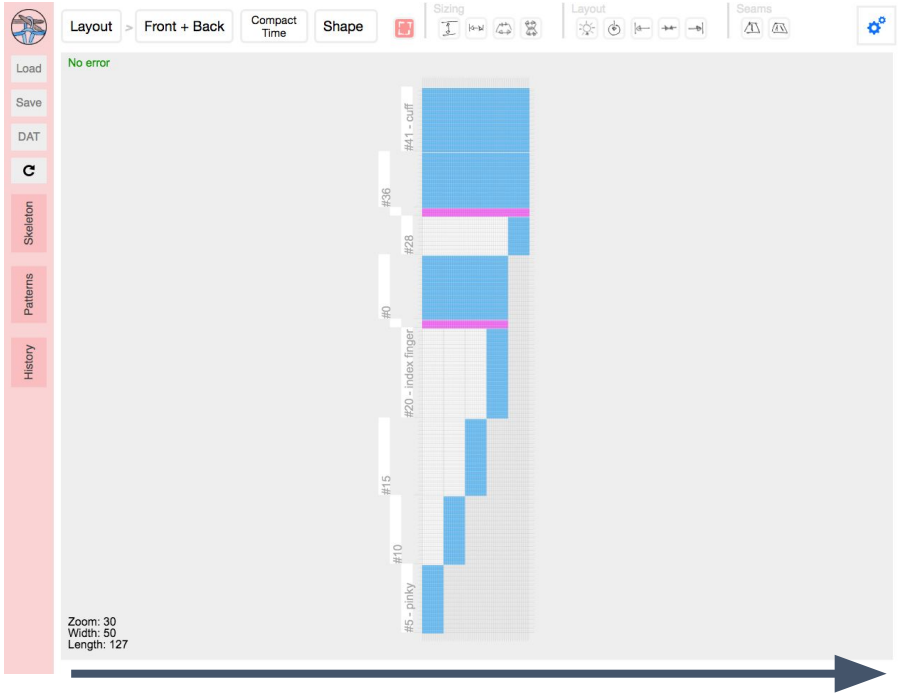


Zoom: 56
Width: 120
Length: 160

3.5x speed



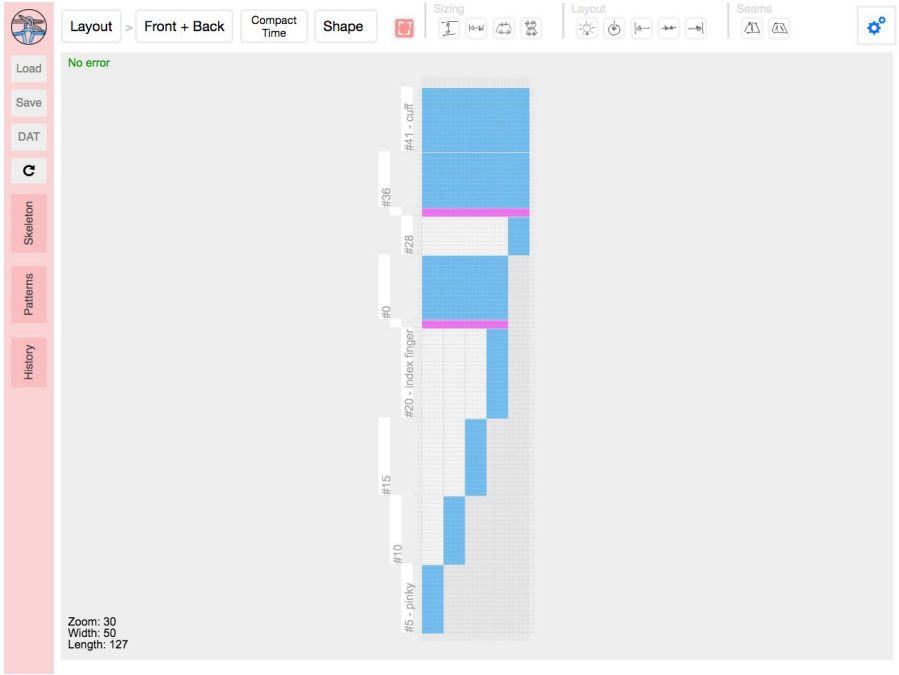
Time-Needle Bed



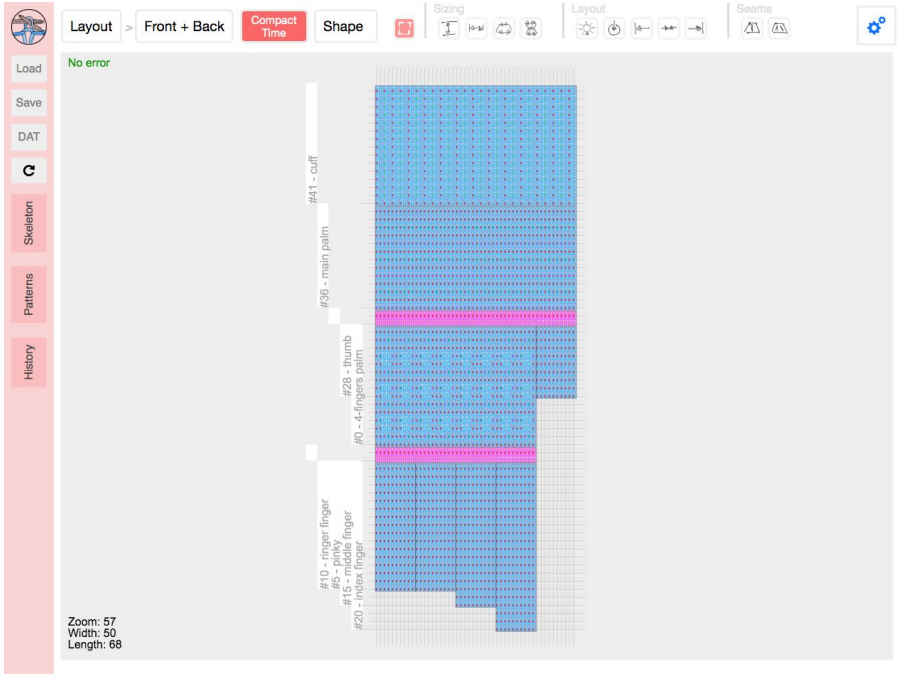
Time

Needles

Time-Needle Bed

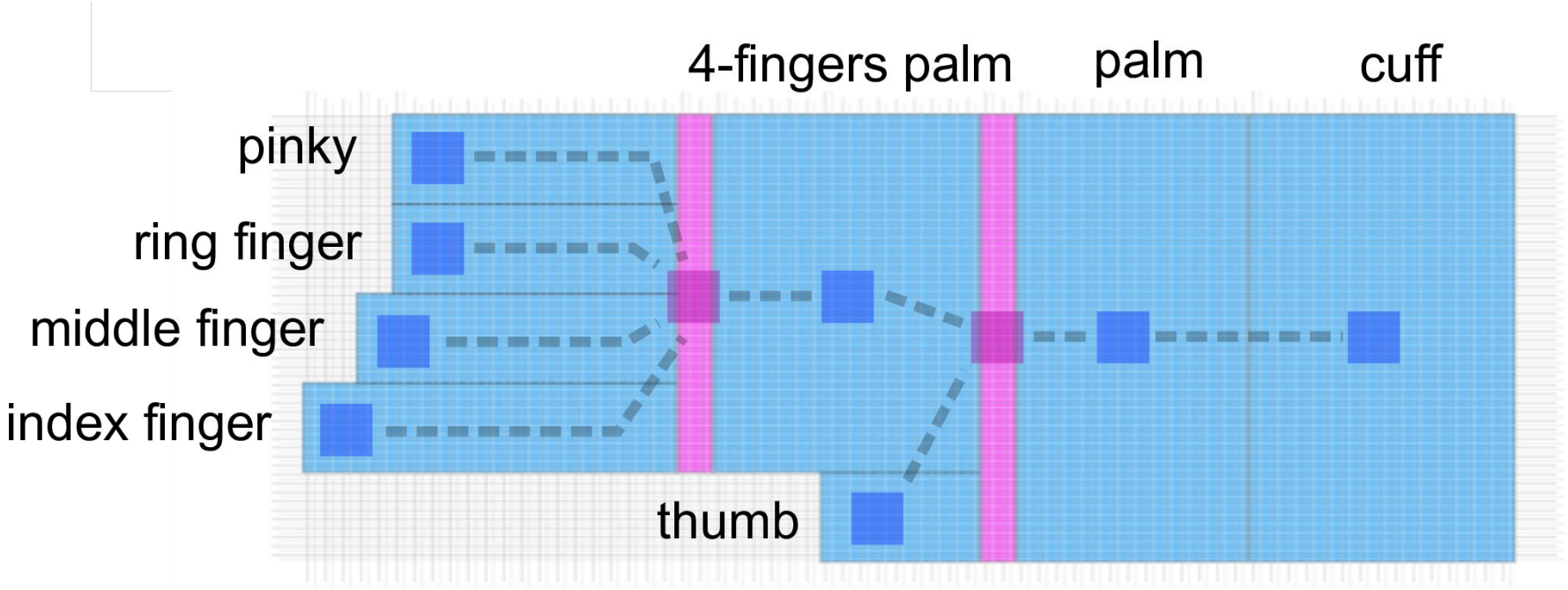


Full version

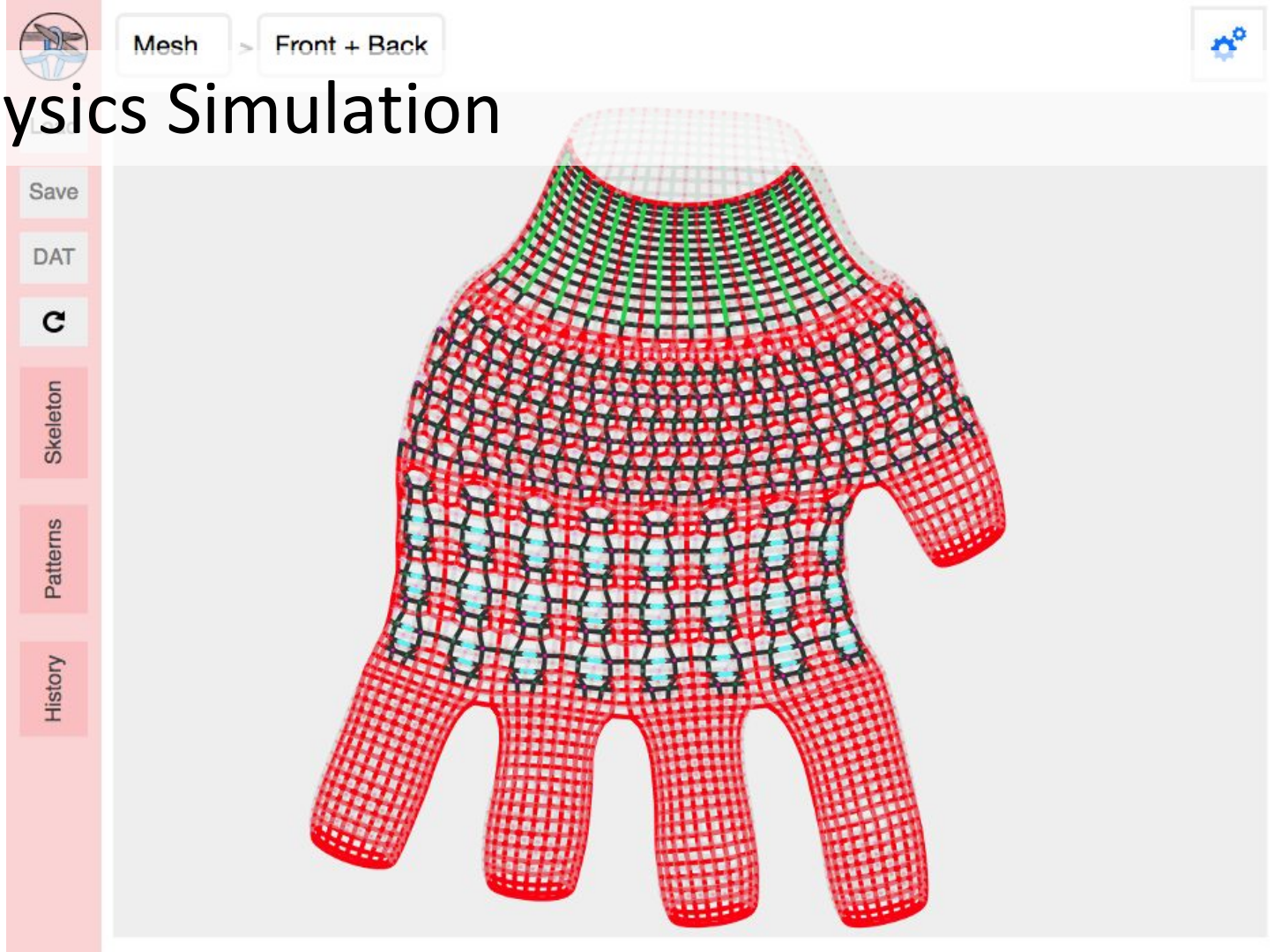


Compact(ed) version

Skeleton Graph



Physics Simulation



Shaping Primitives

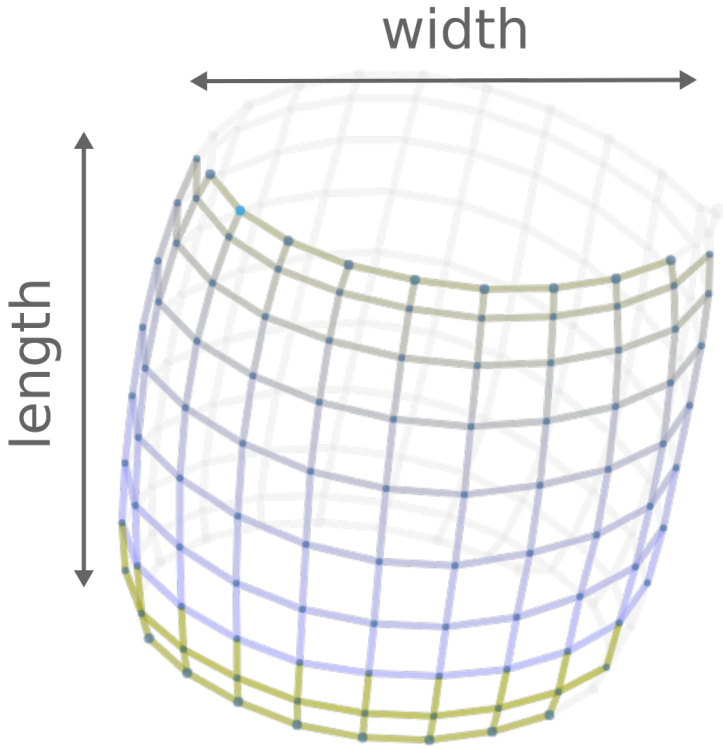
Sheet | Tube

Shaping using

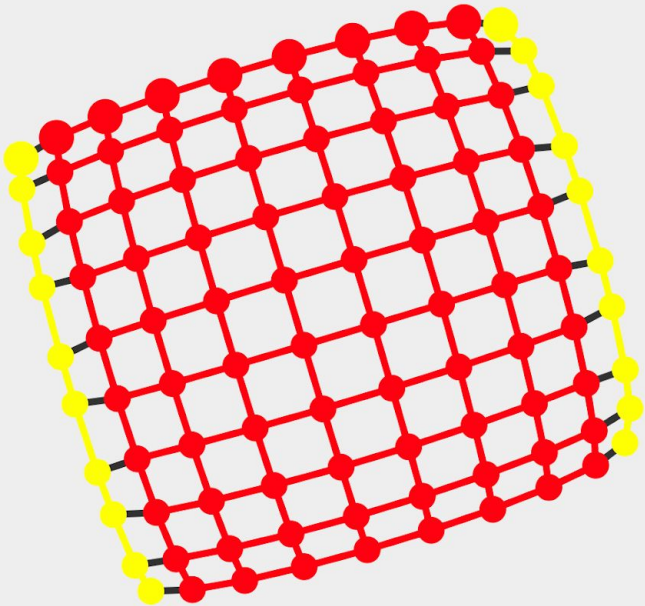
“Stitch increase/decrease”

Interfaces:

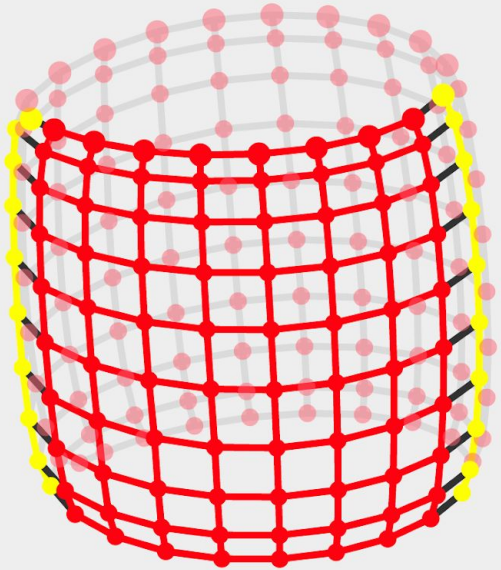
- Top
- Bottom



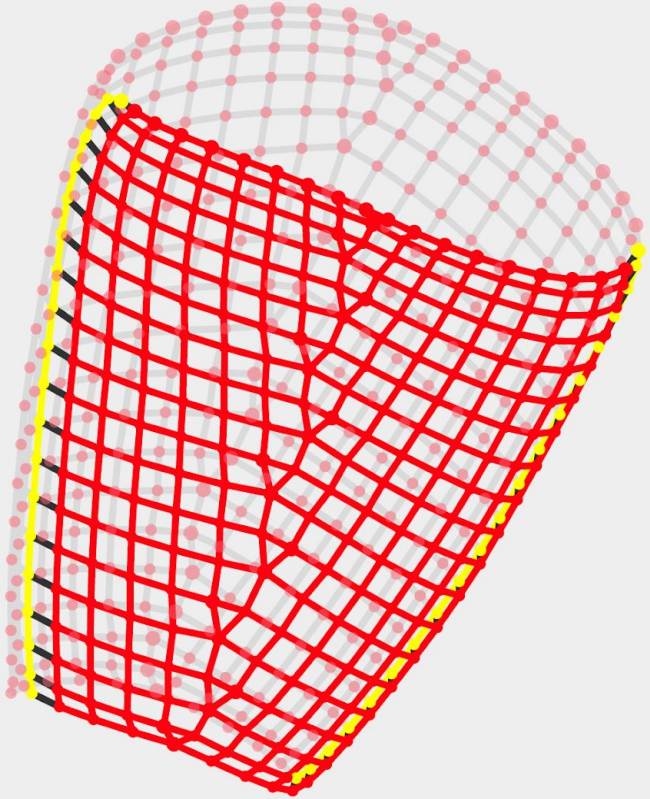
Sheet | Tube (examples)



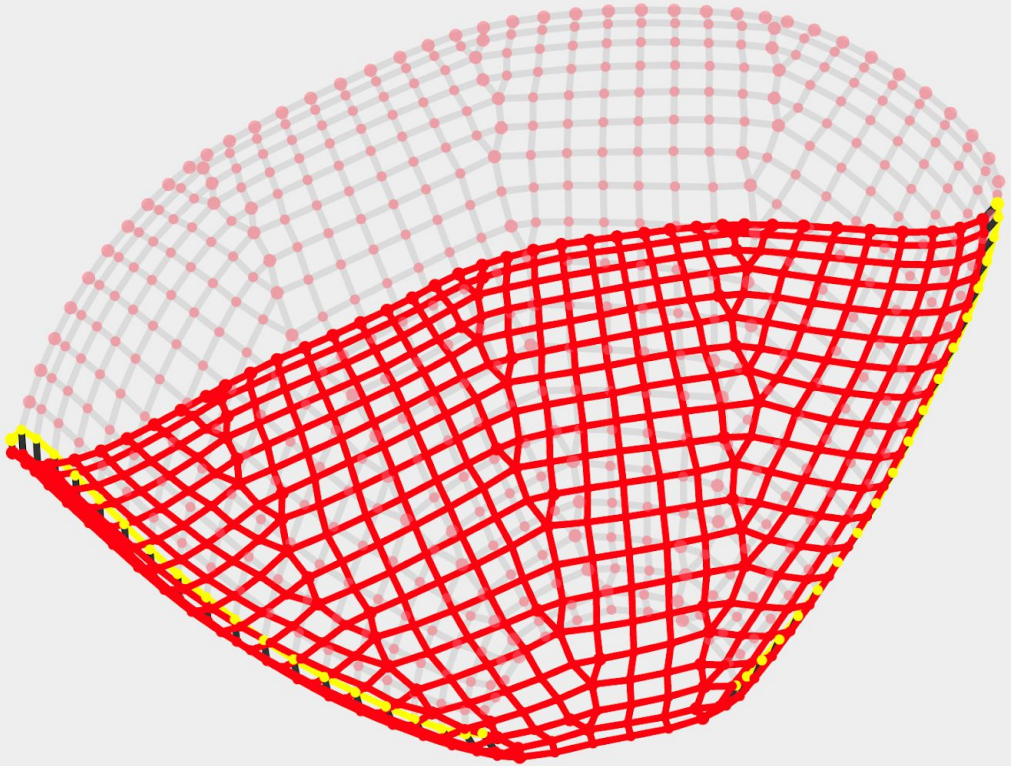
Sheet | Tube (examples)



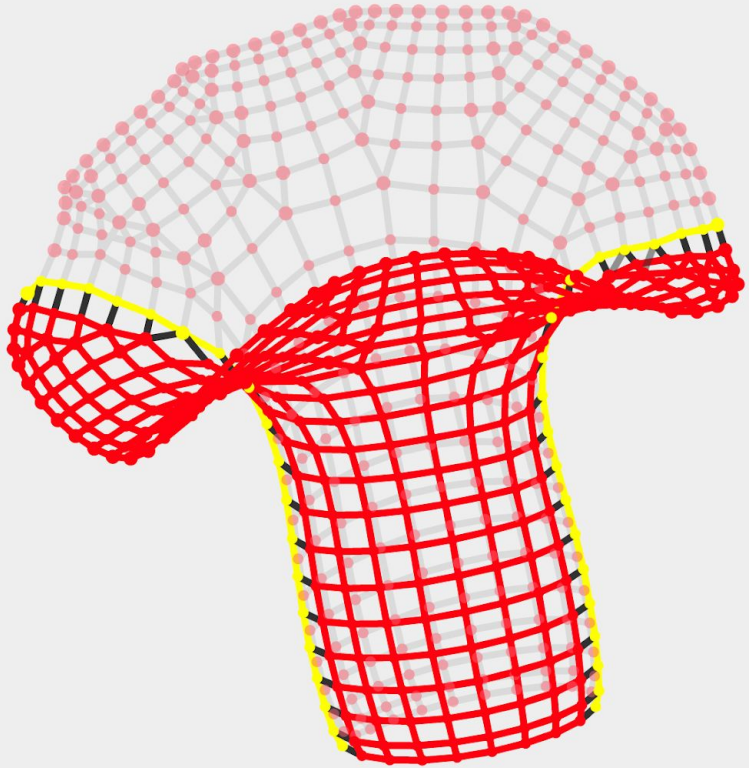
Sheet | Tube (examples)



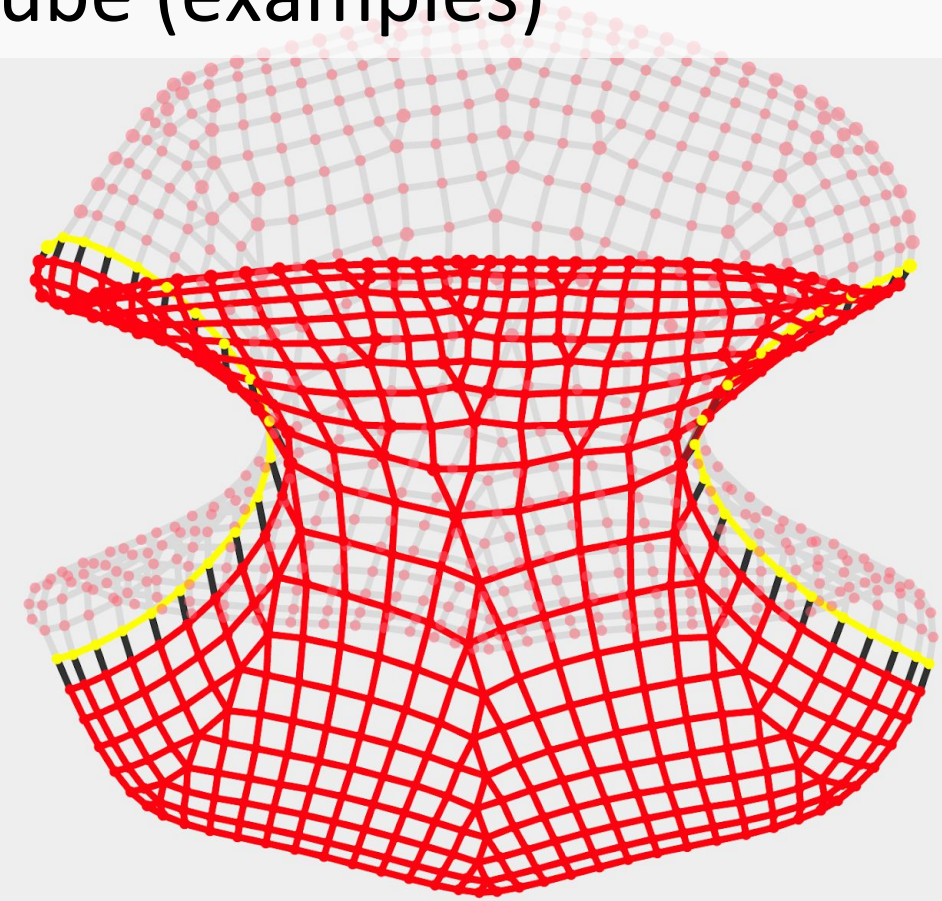
Sheet | Tube (examples)



Sheet | Tube (examples)

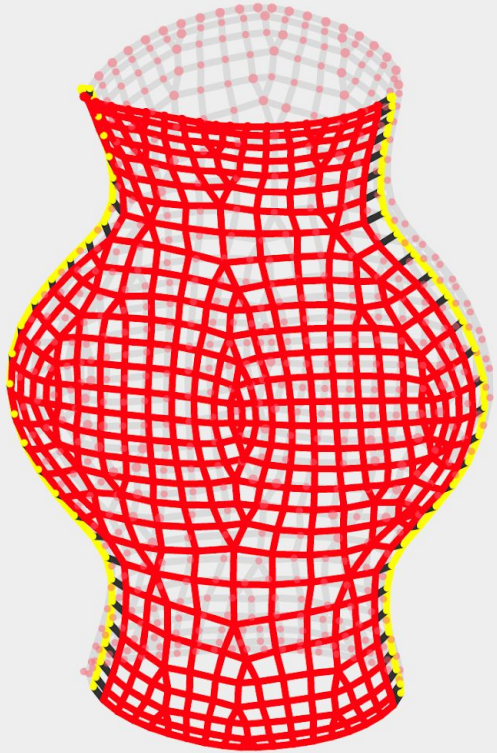


Sheet | Tube (examples)



Mesh > Front + Back

Sheet | Tube (examples)



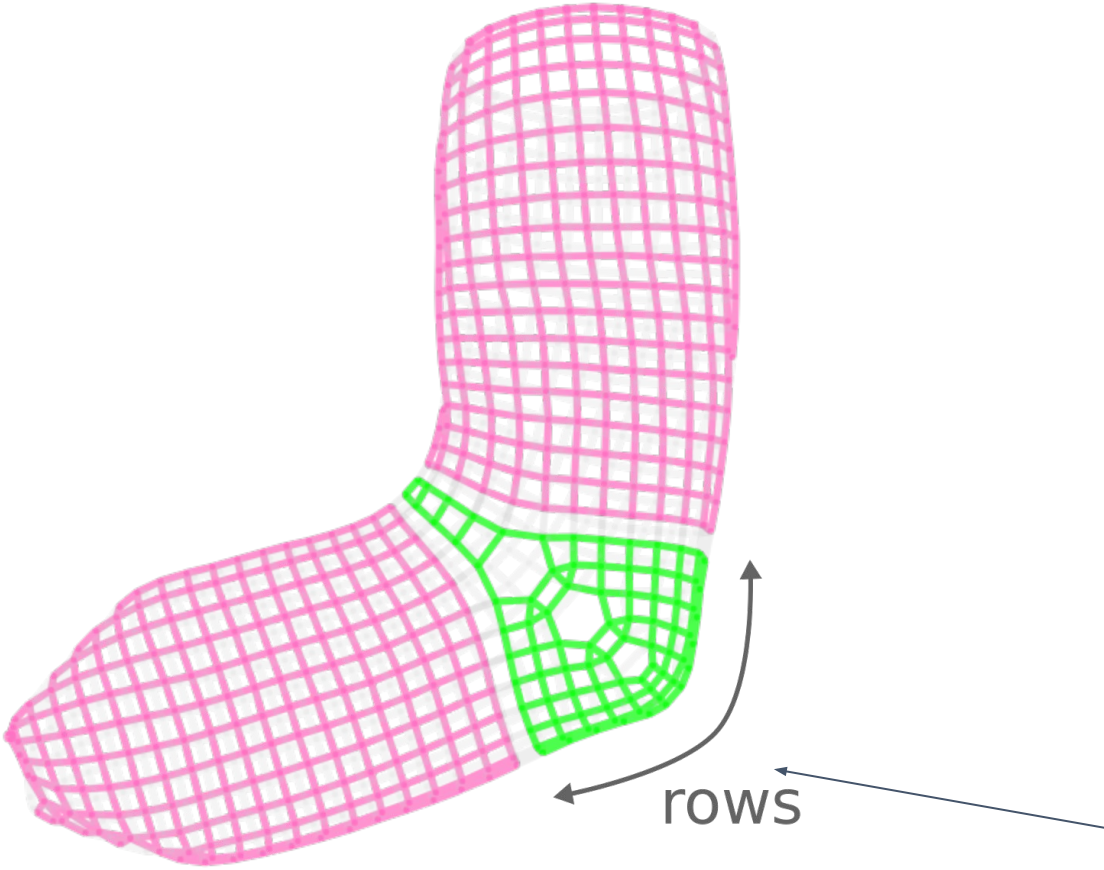
Joint

Shaping using

“Short rows”

Interfaces:

- Top
- Bottom

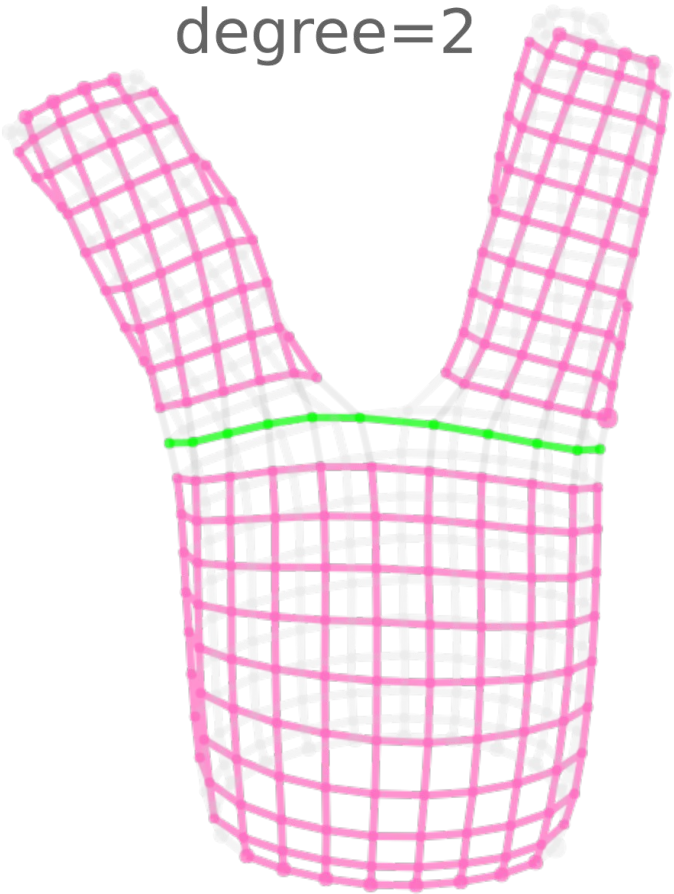


Split | Merge

Topological branching

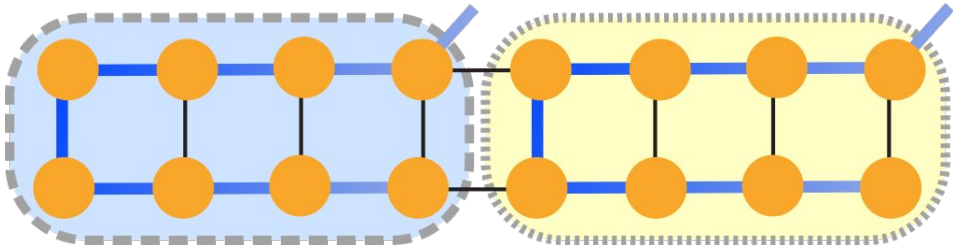
Interfaces:

- Base (1)
- Branches (2+)

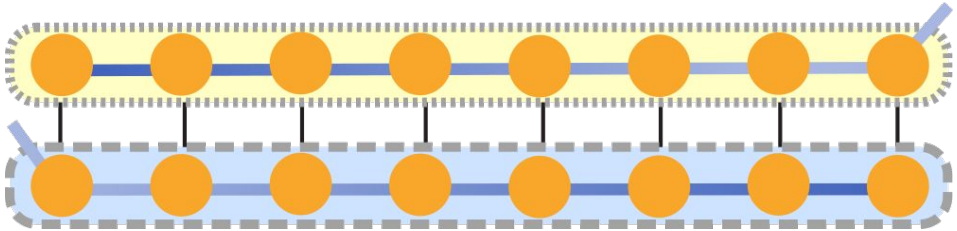


Split | Merge

Folded branches (tubular)



Non-folded branches (flat)



Surface Patterning

Pattern Operations

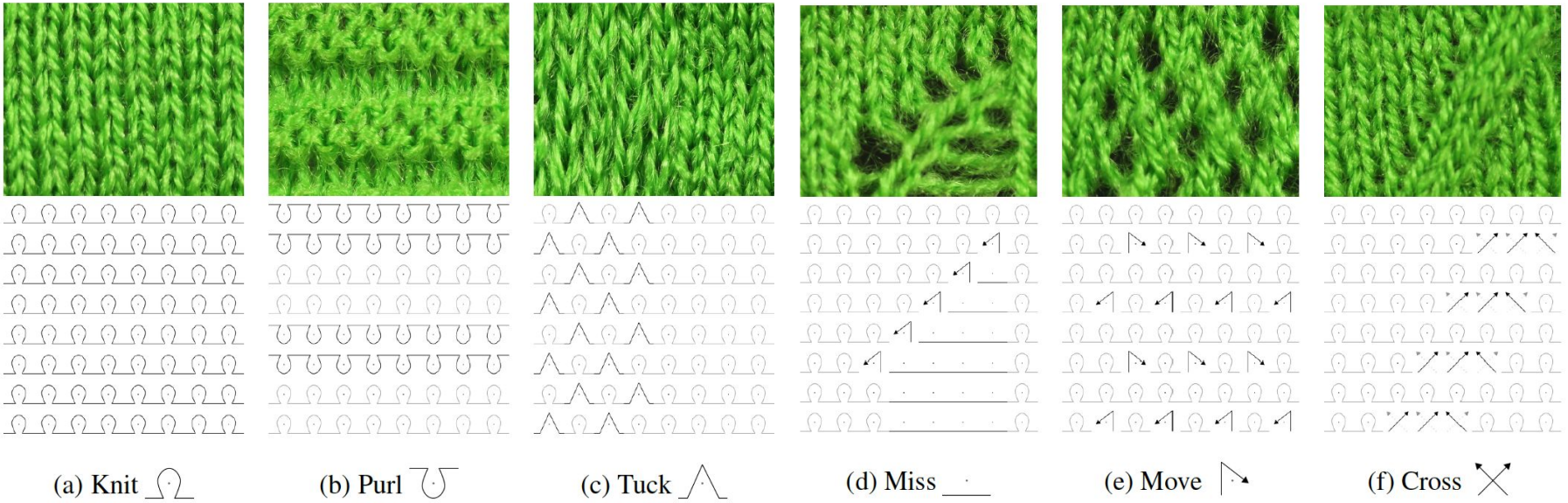
Basic operations

Cross operations

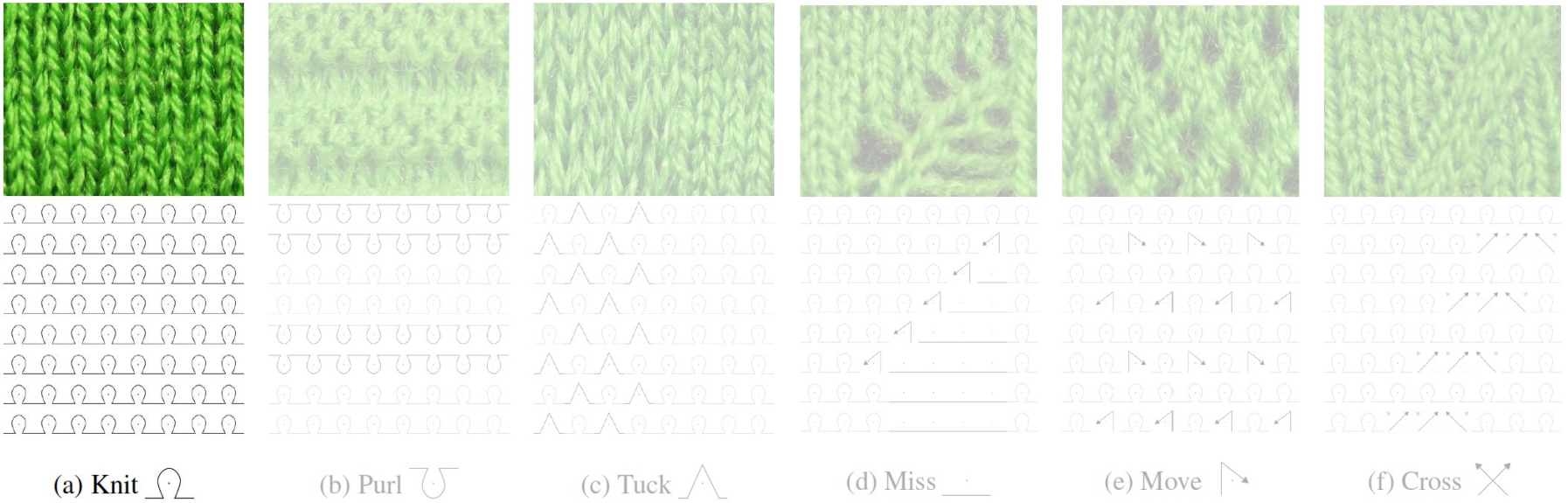
Move operations

S
Stack Order

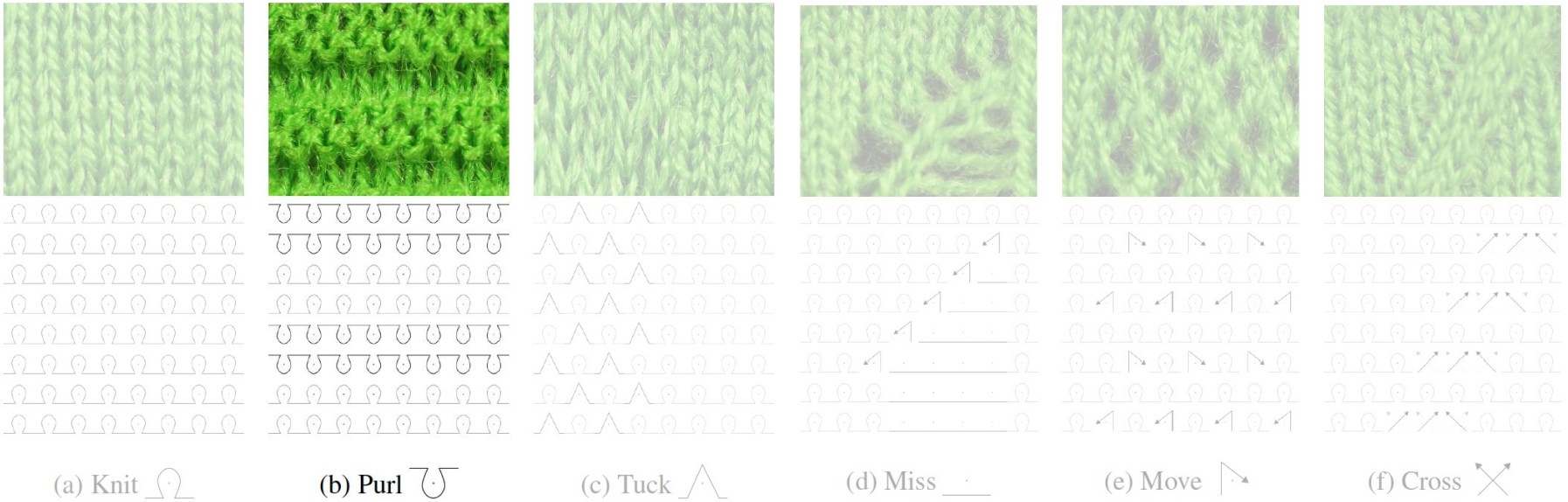
Pattern Operations



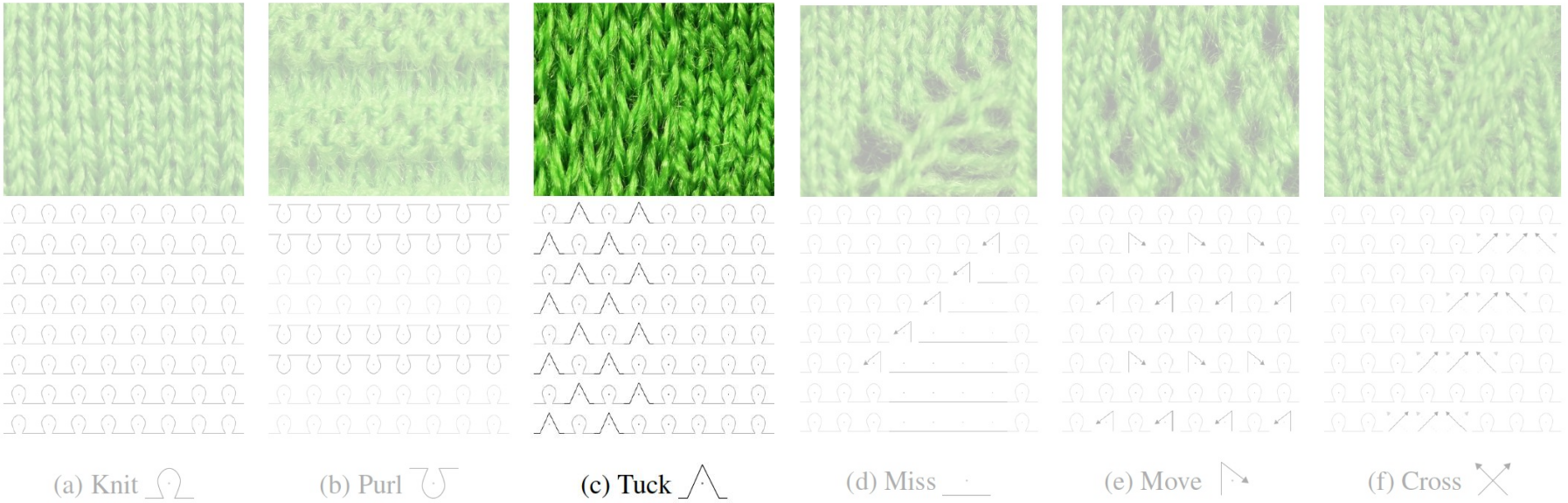
Pattern Operations



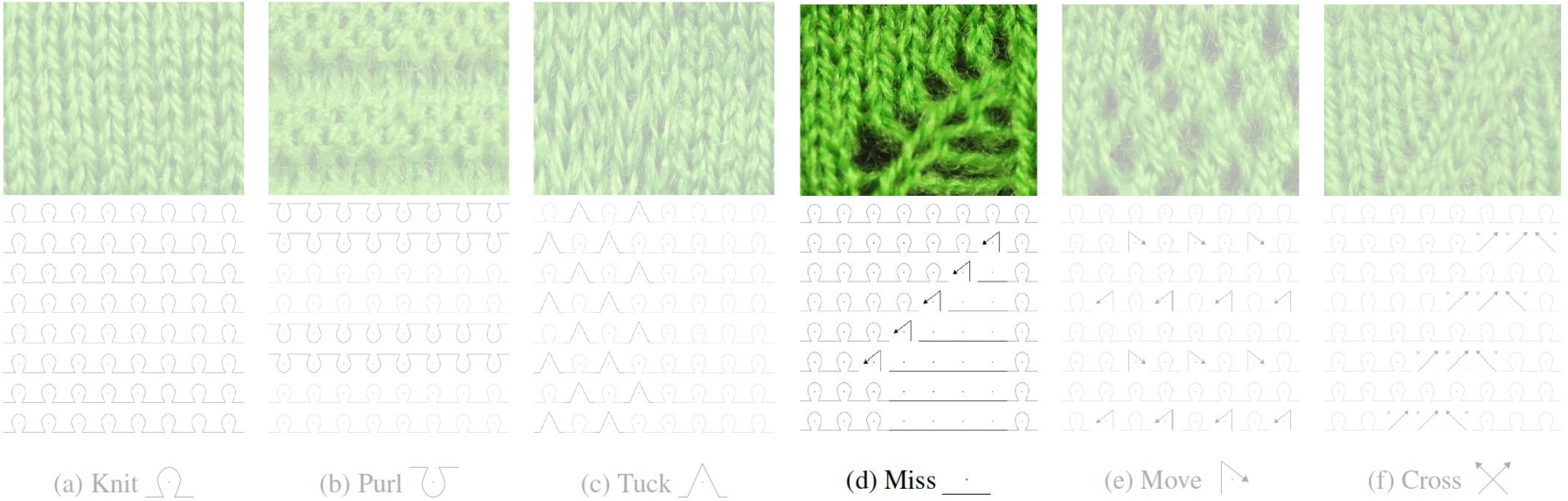
Pattern Operations



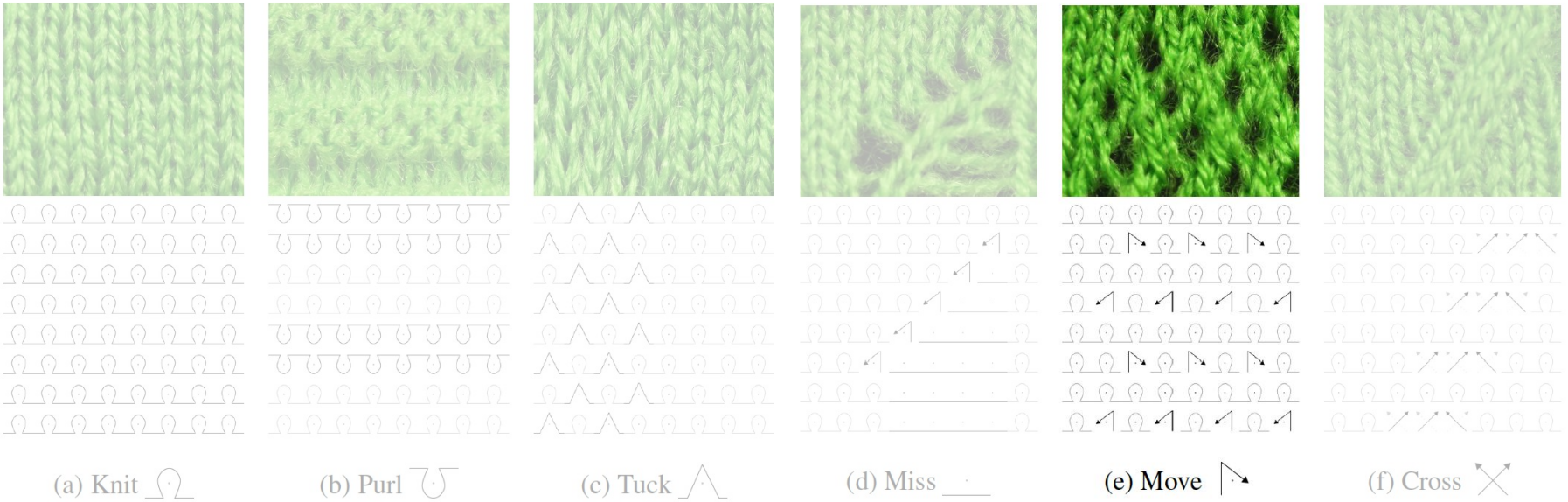
Pattern Operations



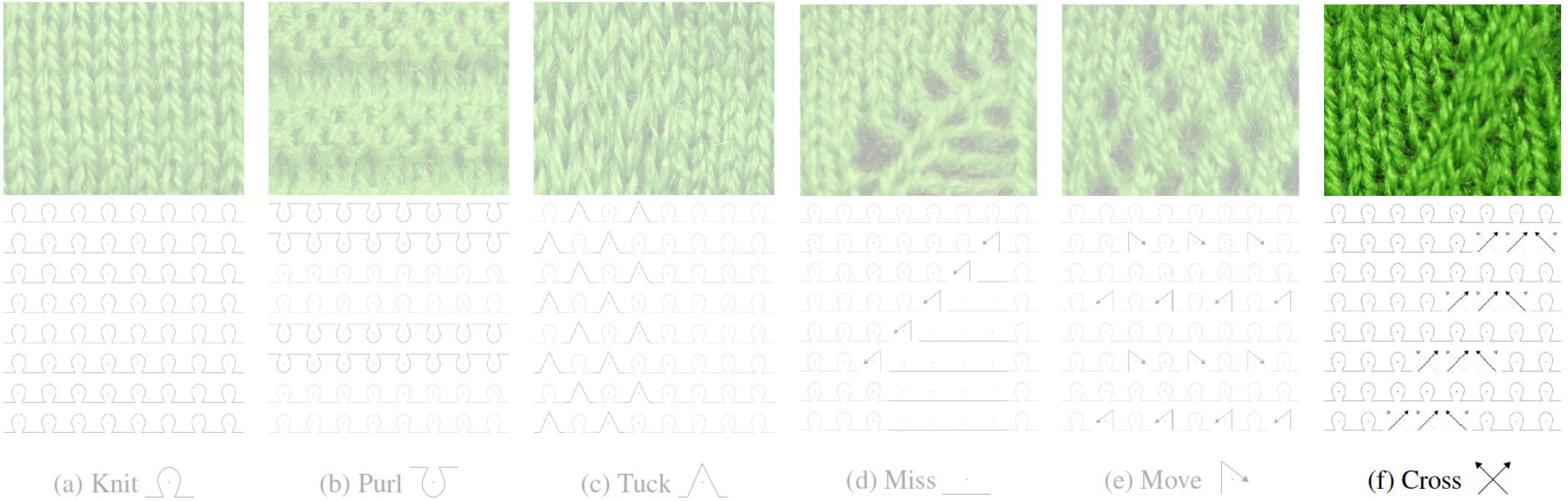
Pattern Operations



Pattern Operations



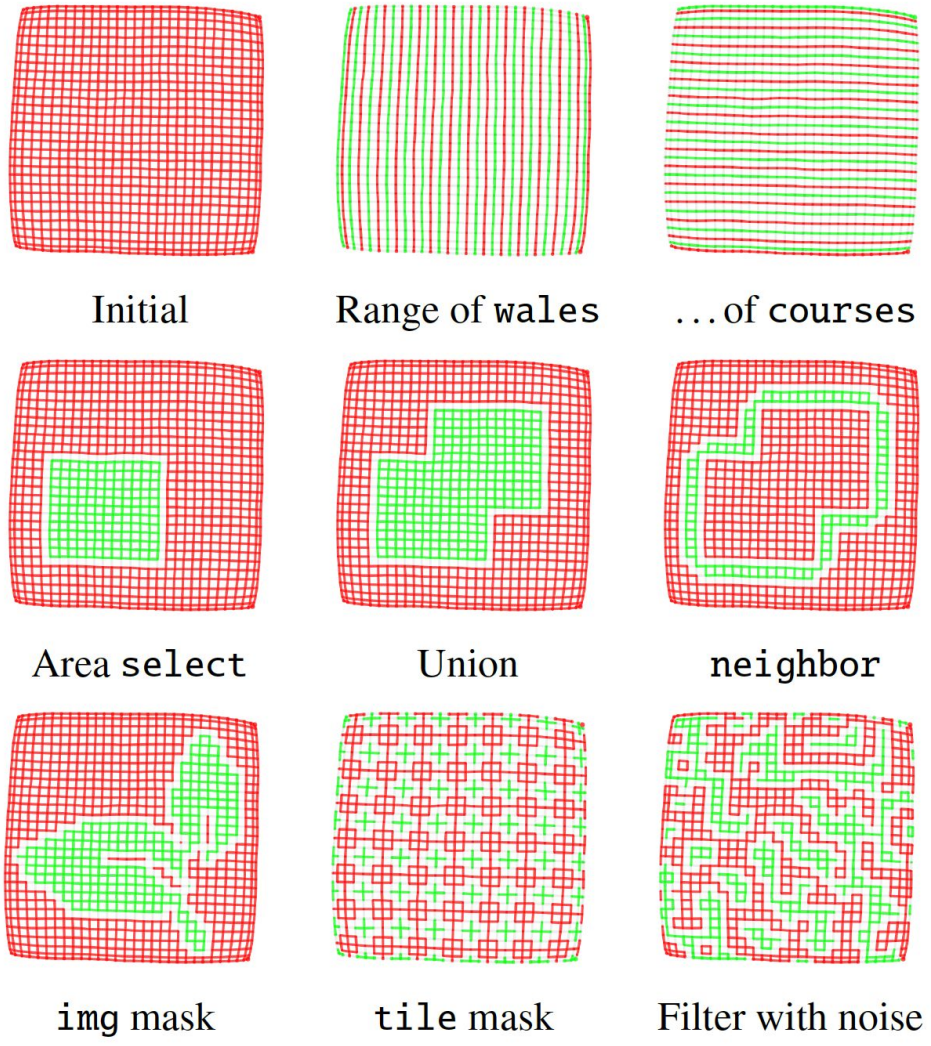
Pattern Operations



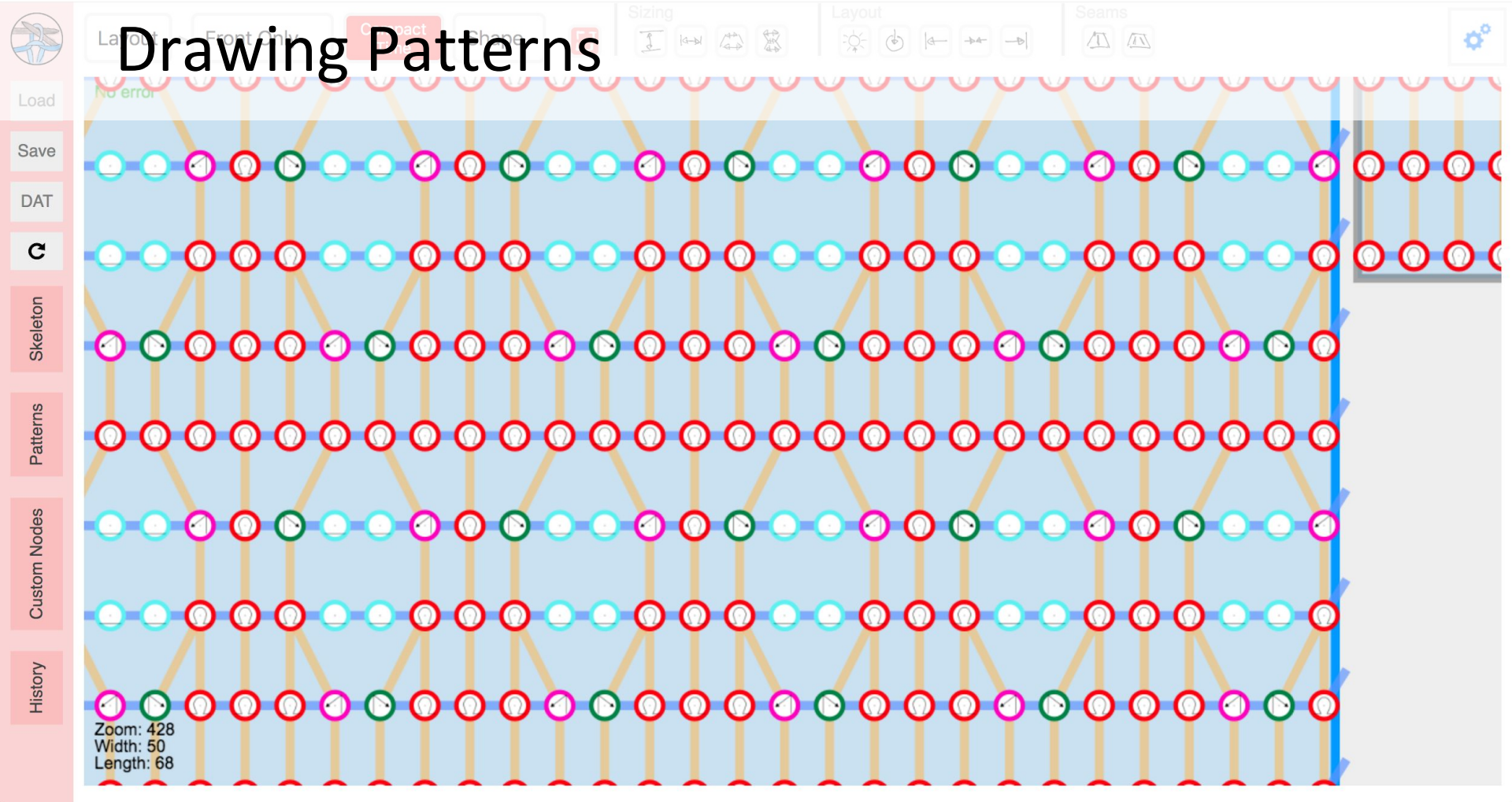
Pattern Queries

- User programming
- In-browser editor
- Based on Javascript

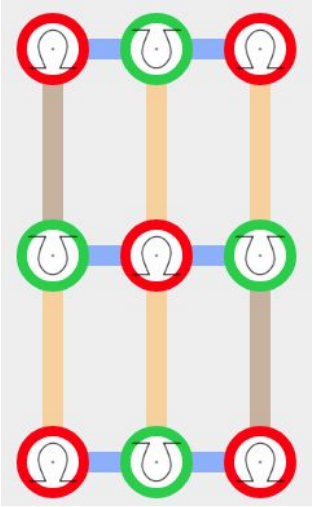
Query = `select`
Operation = `apply`



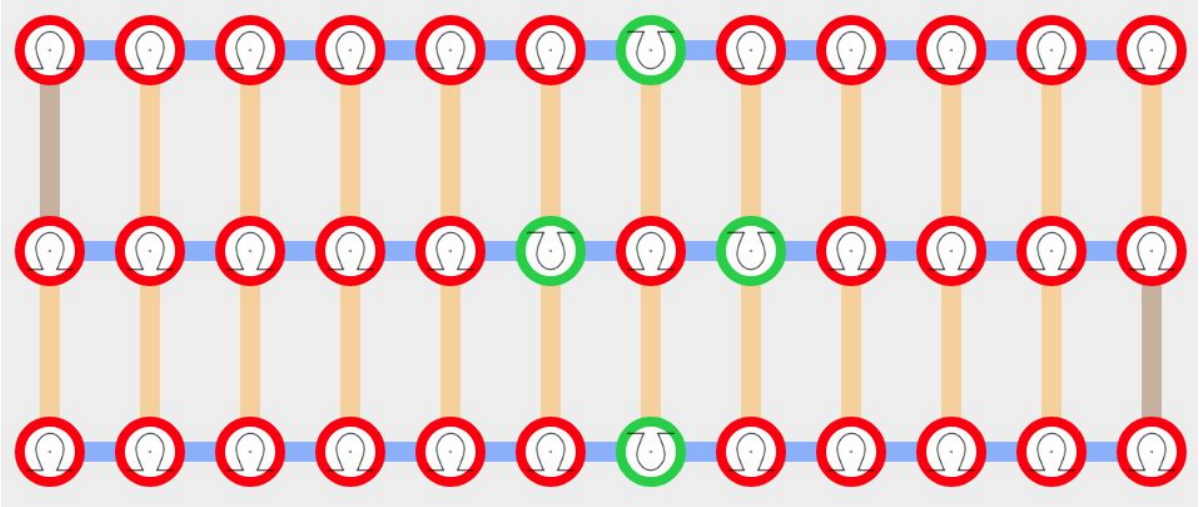
Drawing Patterns



Pattern Layer Resampling

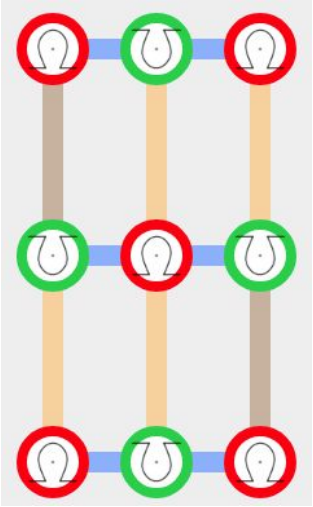


Base Pattern

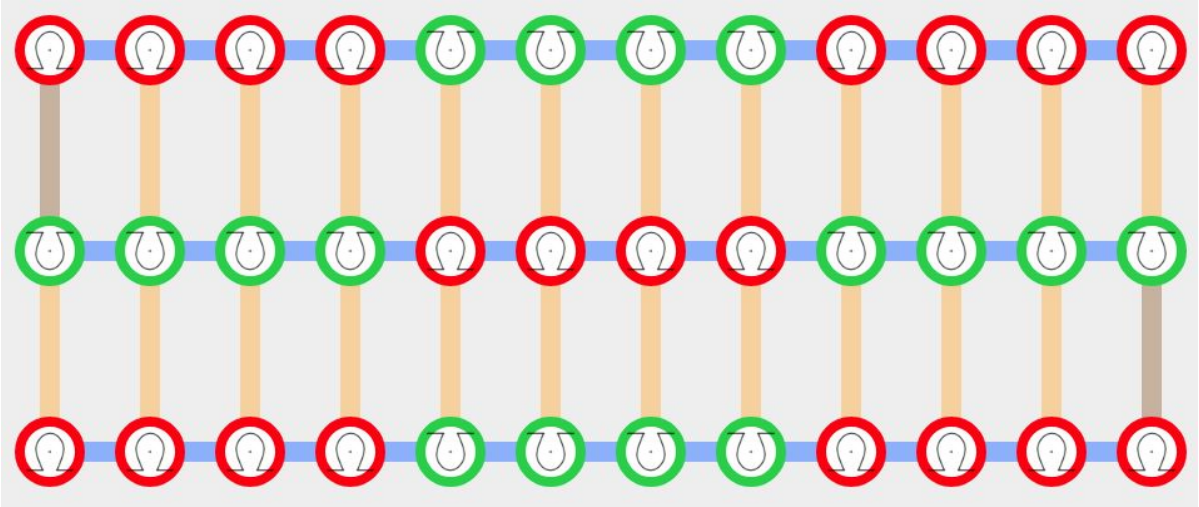


Singular layer behaviour

Pattern Layer Resampling

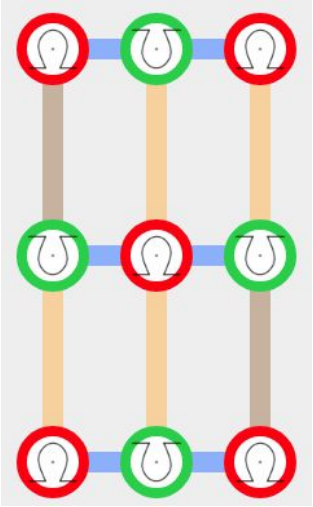


Base Pattern

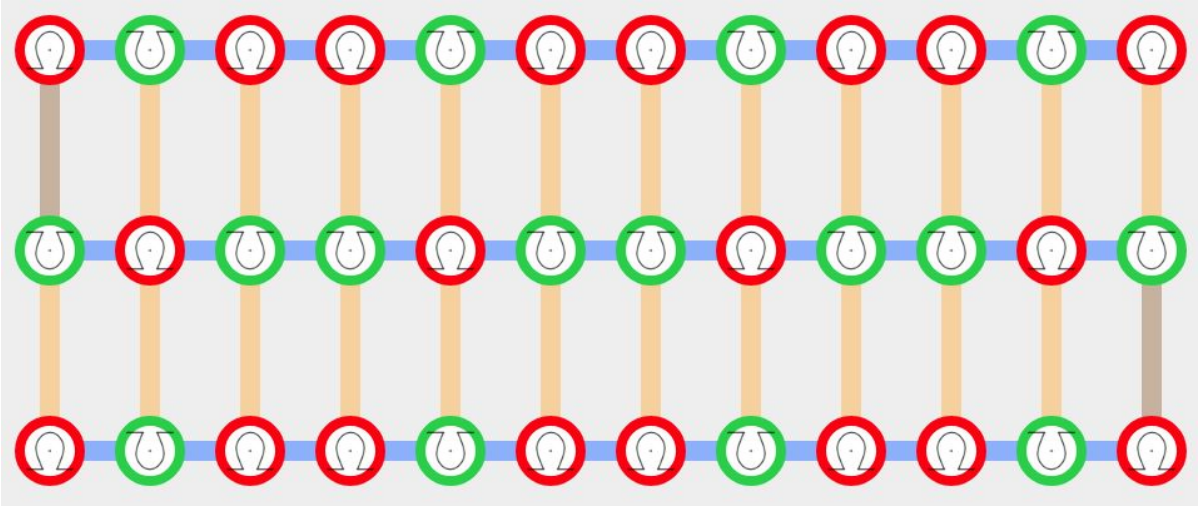


Scalable layer behaviour

Pattern Layer Resampling



Base Pattern



Tileable layer behaviour

Knitting

Results

Knitting | Shaping

Results

Full Garments

Infinity scarf with custom lace pattern

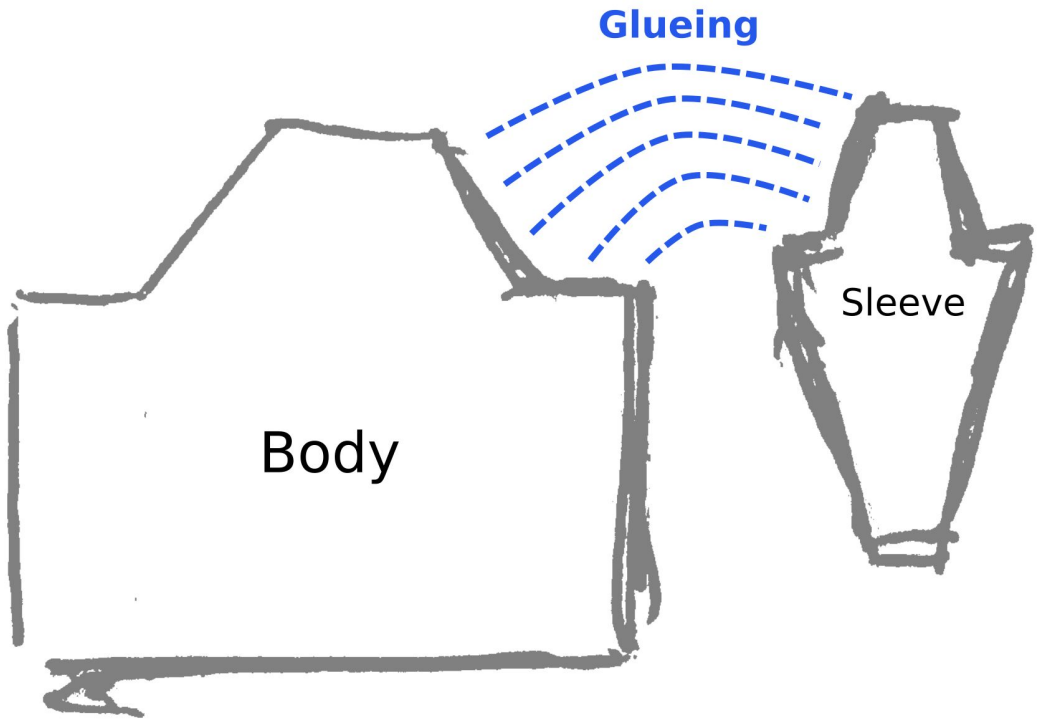
Socks

Full Garments

Miniature Prototypes

Patterned Glove

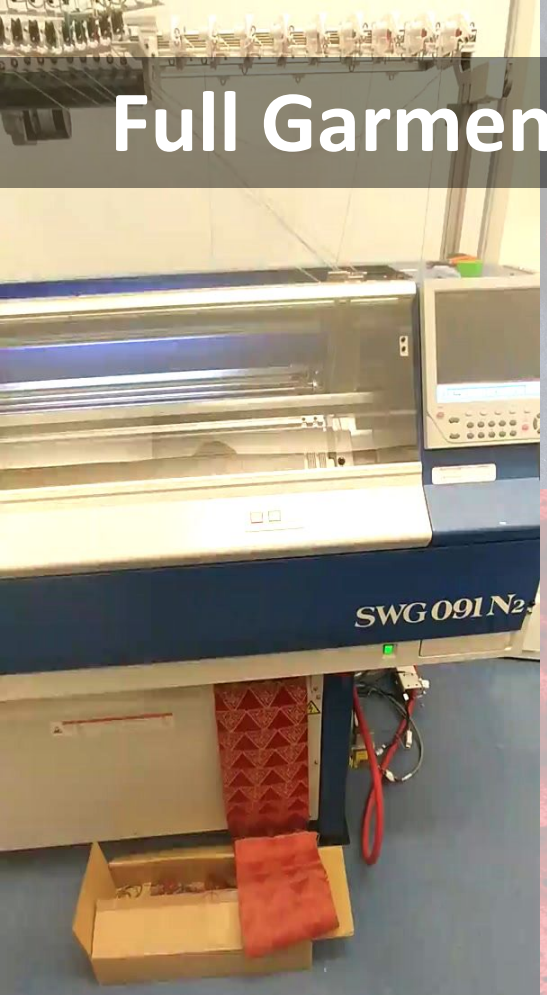
Challenge 1: Complex Interface Interactions

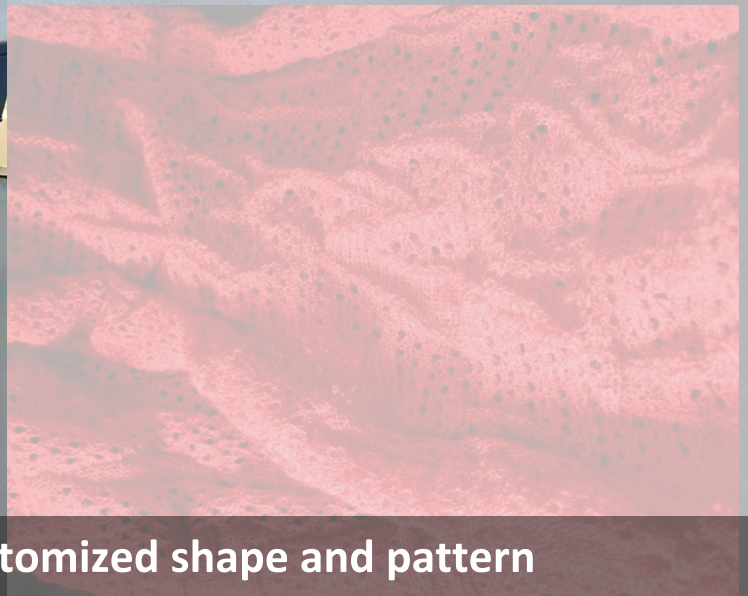


Challenge 2(a): Supporting full-size garments

- Computational scalability: adult-size garments are made of a very large number of stitches

Full Garments

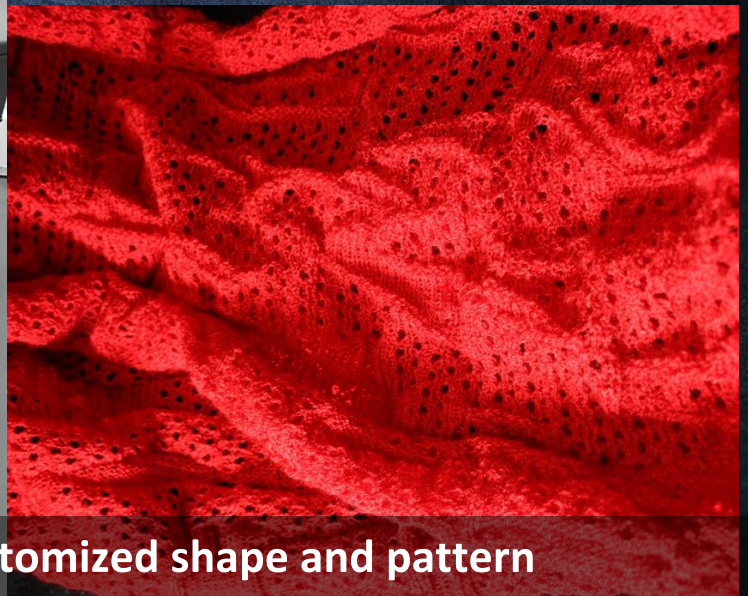




Scarves with customized shape and pattern

Socks

Full Garments



Scarves with customized shape and pattern

Socks

Full Garments

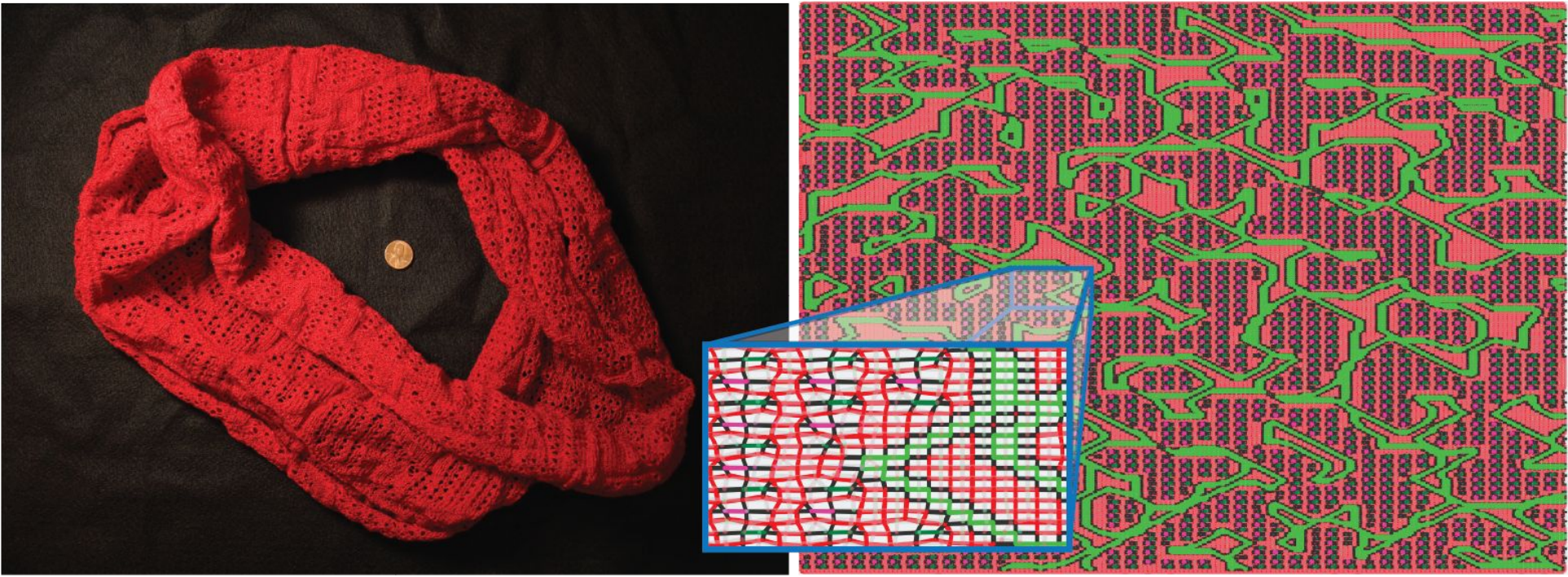
Miniature Prototypes

Patterned Glove

Knitting | Patterns

Results

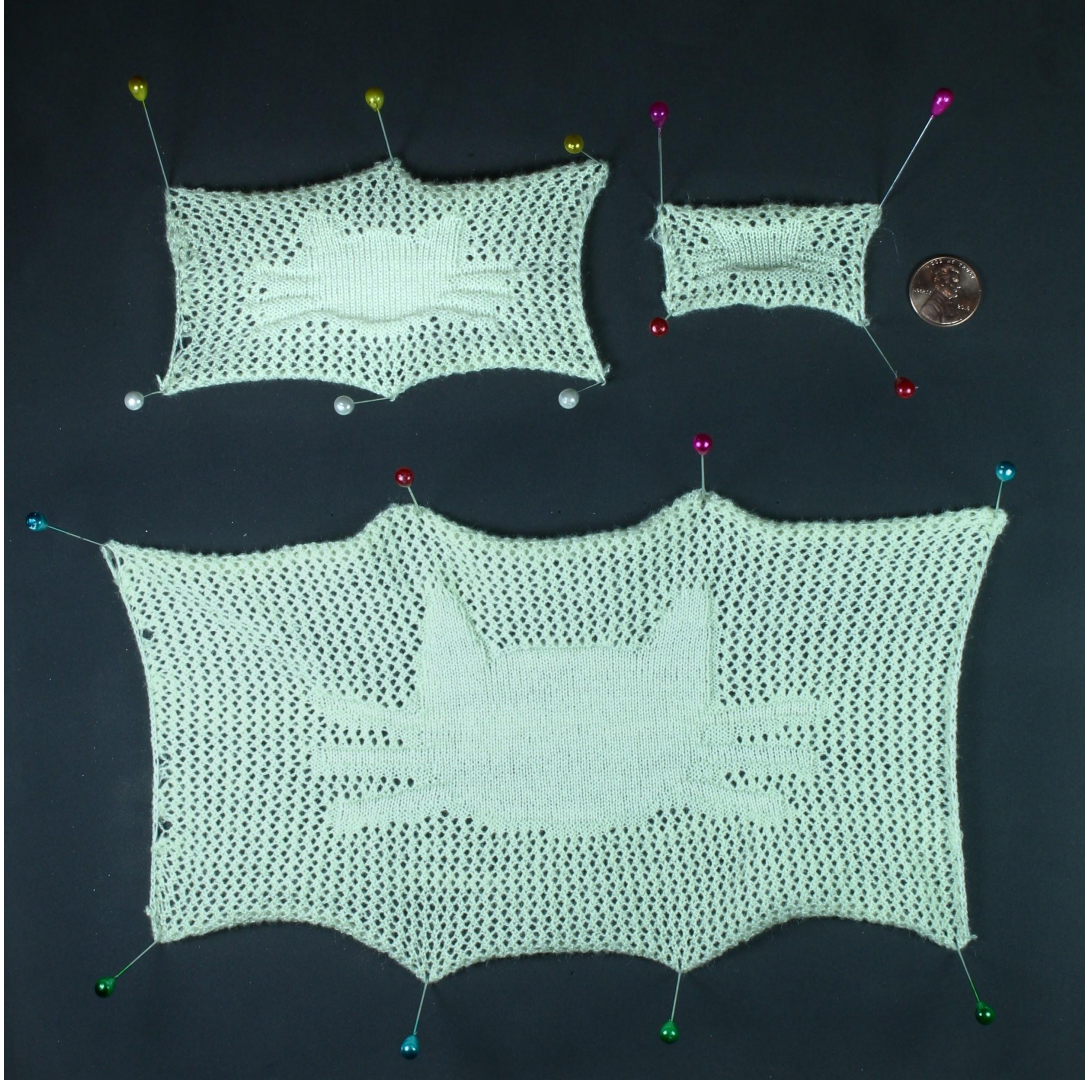
Complex Patterns



Resizing Layers

Cat = *scalable*

Background = *tileable*



Pattern -vs- Shape

Challenge 2(b): Supporting full-size garments

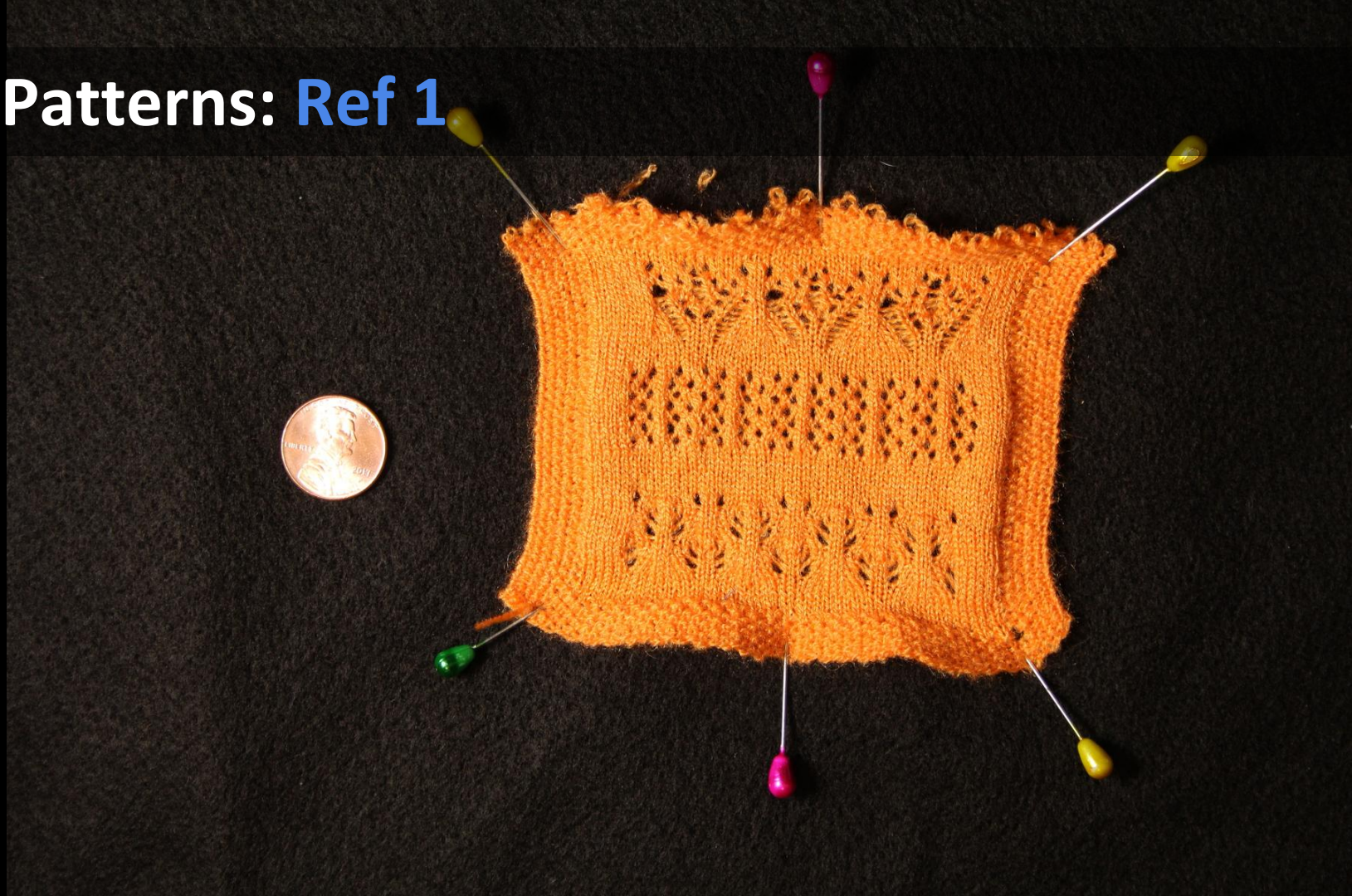
- Computational scalability: adult-size garments are made of a very large number of stitches

- User scalability: specifying individual stitches for such structures becomes impractical

User

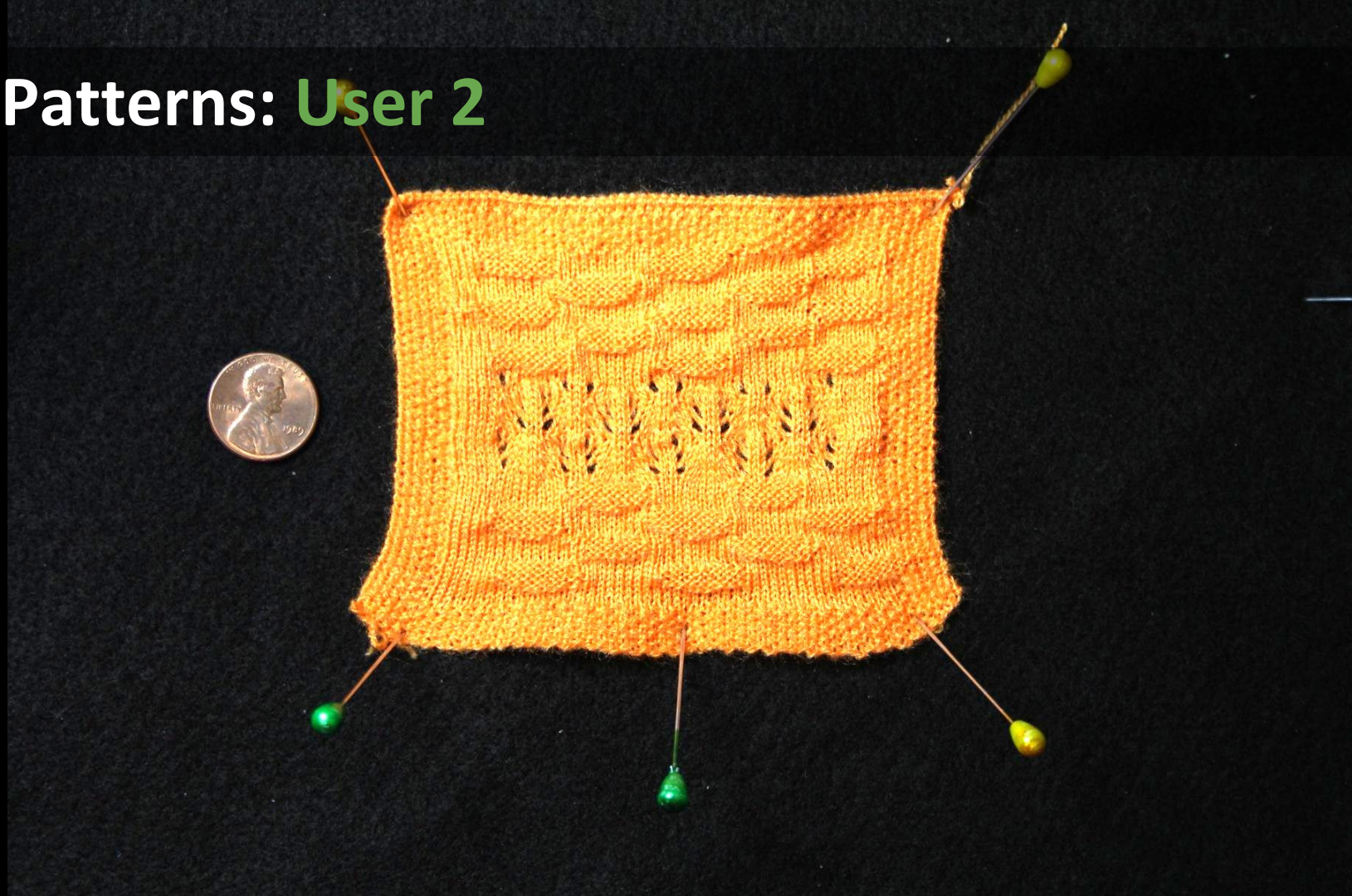
Results

Lace Patterns: Ref 1



Lace Patterns: User 1

Lace Patterns: User 2

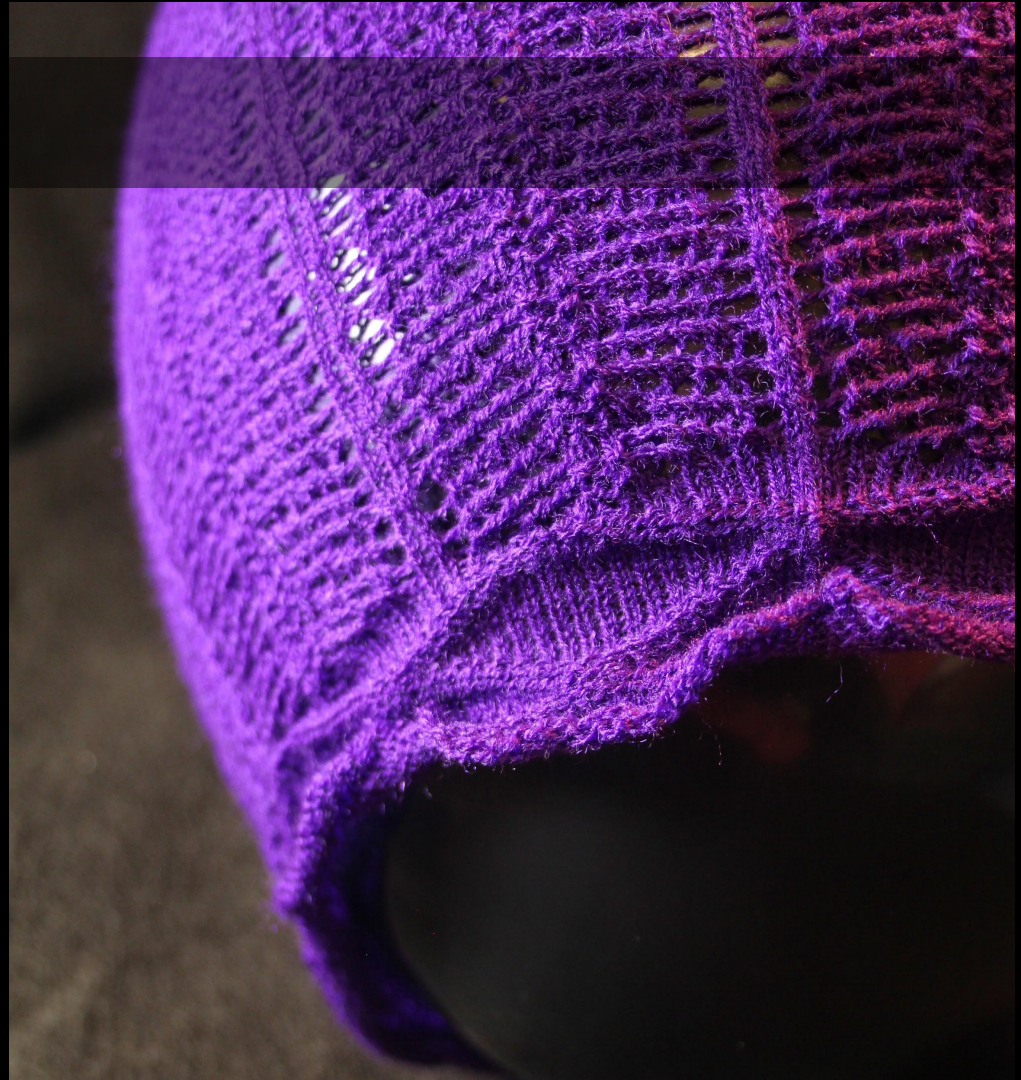


Pattern on Wristband

Hats

Hats

Hat of User 1



Gloves

Glove of User 1: 3 iterations

Challenge 3: Modeling the Manufacturability

- Topological correctness is not sufficient.
- Machine parameters are important.
- When it fails, why does it fail?

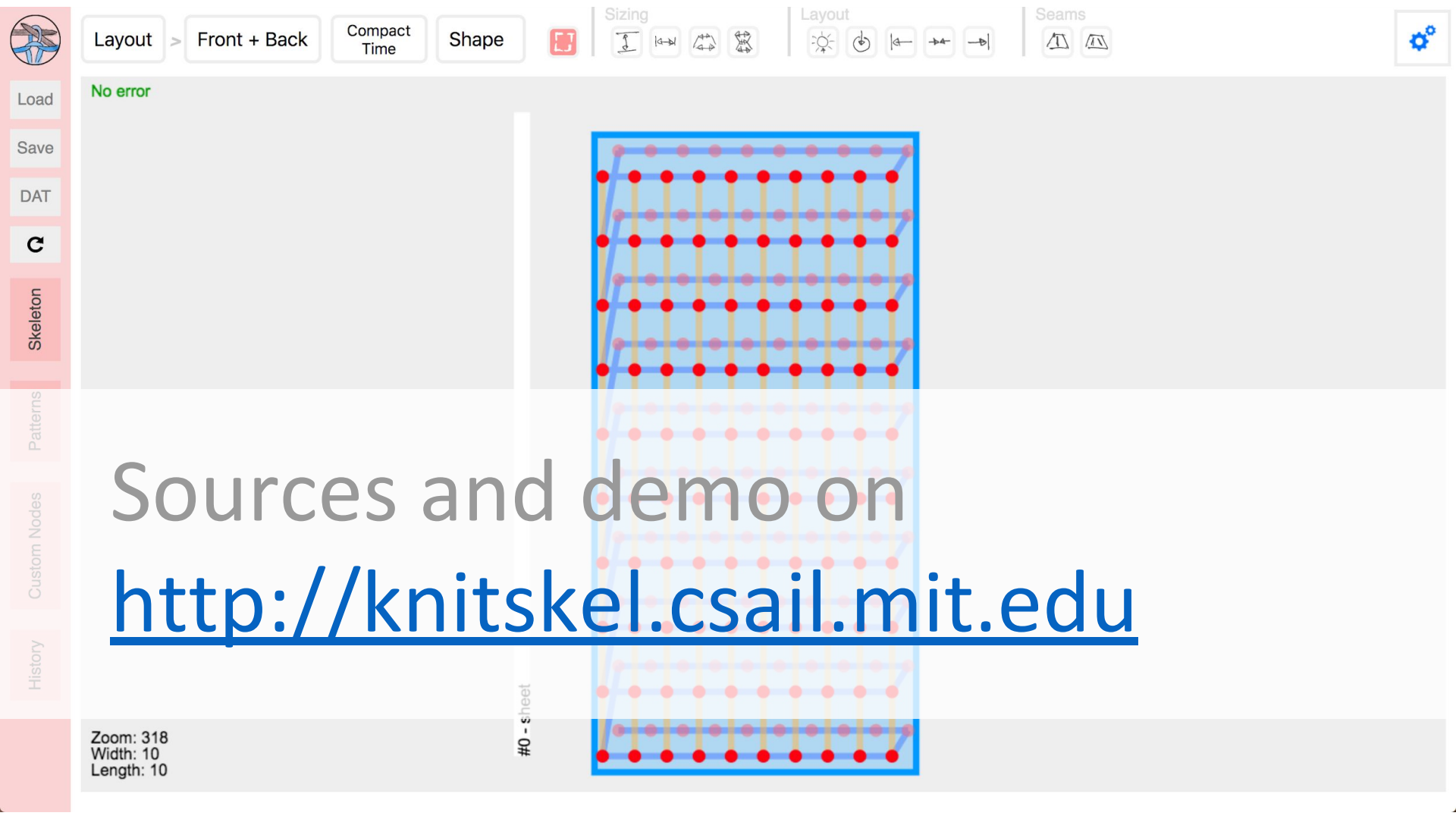
Take-aways

Contributions:

- New fully parametric design tool for knitting
- Complex pattern design on top of our primitives
- Working customization for non-expert users

Challenges:

- Parameterizing complex shape interactions
- Computational and user scalability
- Modeling the full manufacturability


Layout
Front + Back
Compact Time
Shape
Sizing
Layout
Seams
Load
Save
DAT
Skeleton
Patterns
Custom Nodes
History
No error
Sources and demo on
http://knitskel.csail.mit.edu
#0 - sheet
Zoom: 318
Width: 10
Length: 10