

Curl Quantization for Automatic Placement of Knit Singularities

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(BU)

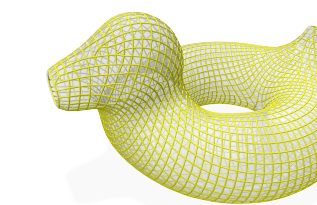


(LS)



(NEU)



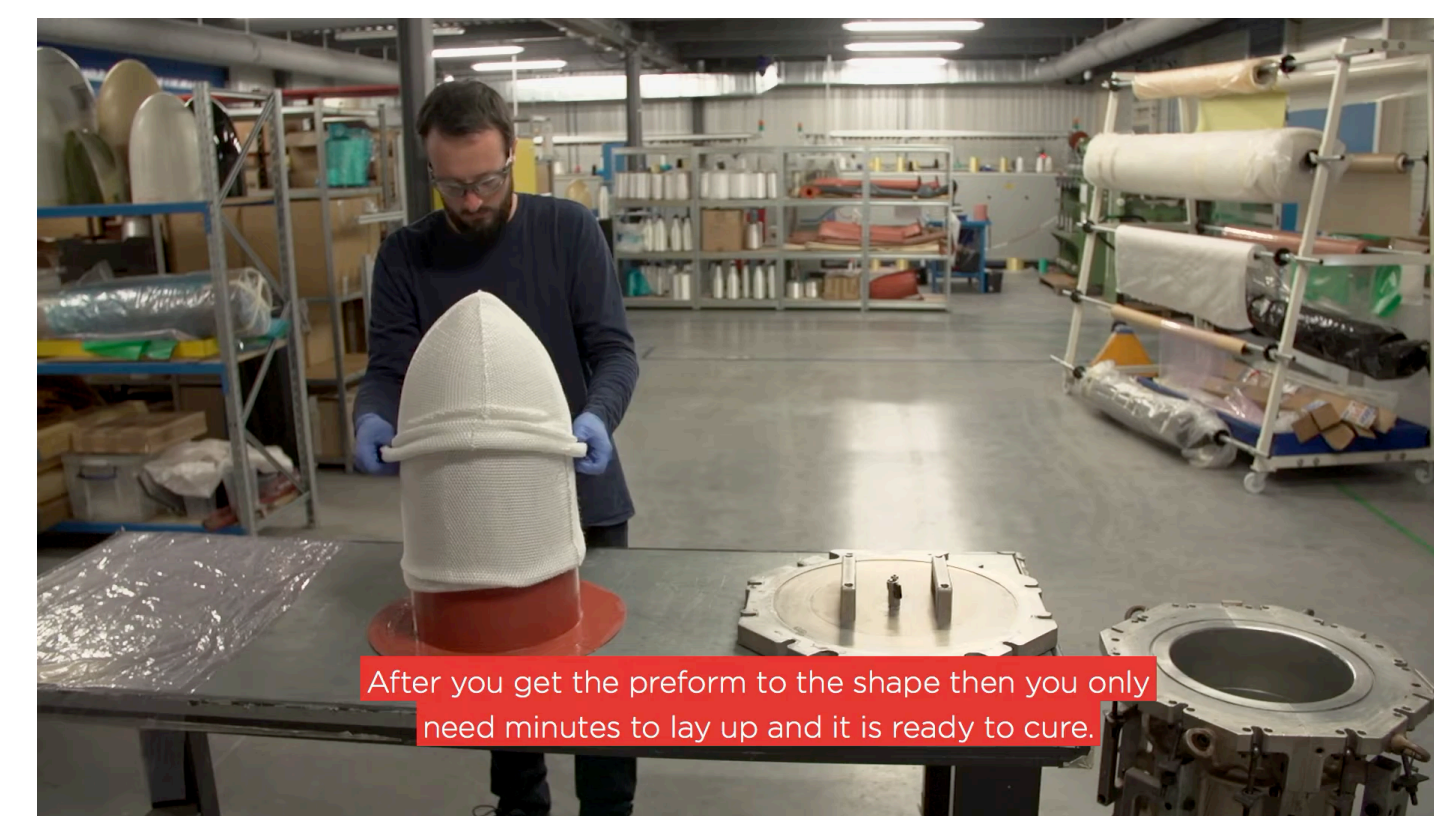


Knitting applications

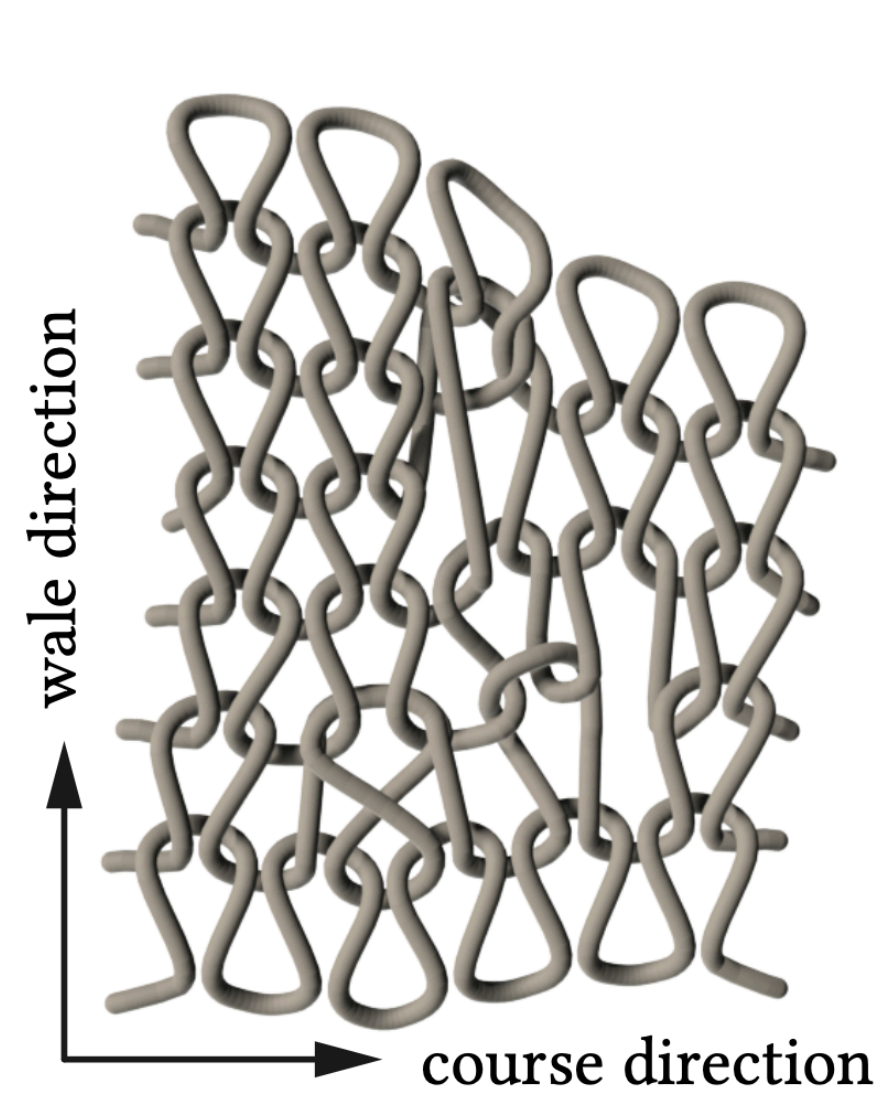
Garments



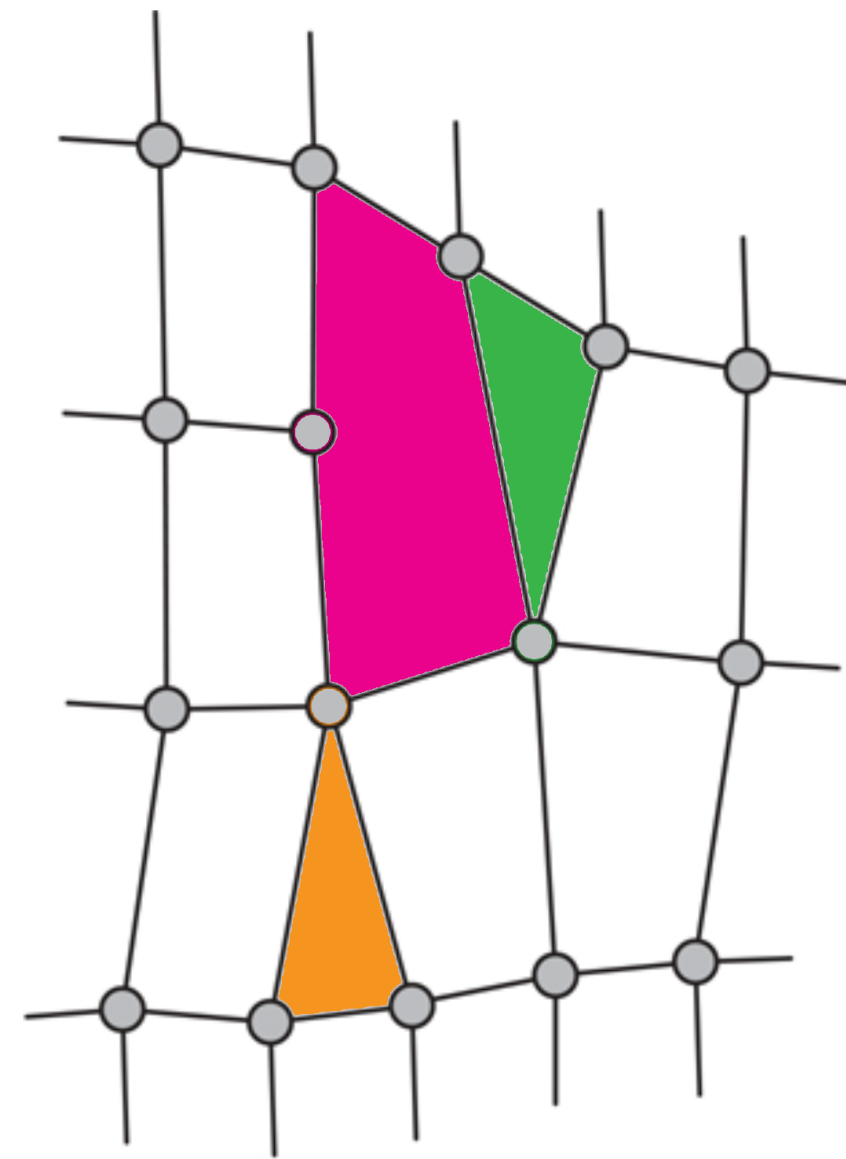
Composites



Yarn structure is abstracted by a *knit graph*



Yarn



Knit graph

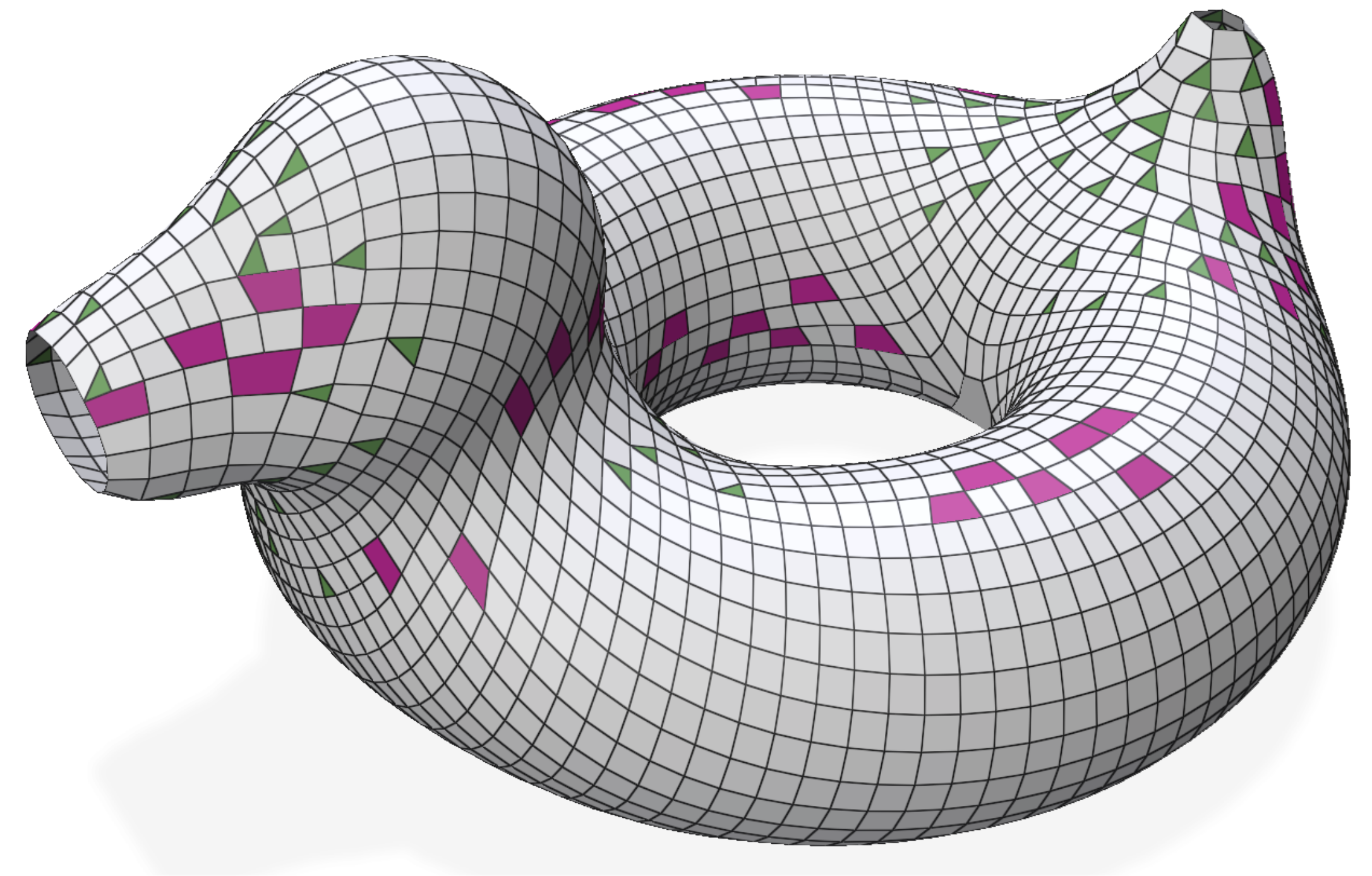
Stitch irregularities:

short row end

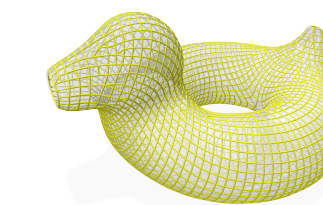
increase

decrease

induce **curvature**

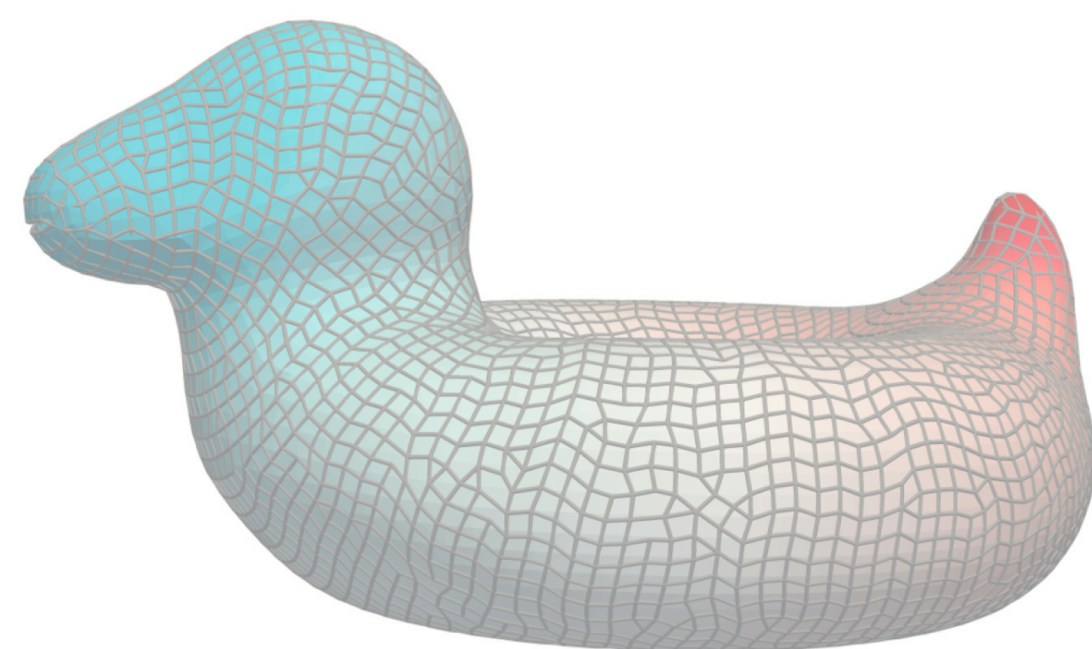


Goal: given target shape,
place stitch irregularities
to make knit graph
as uniform as possible

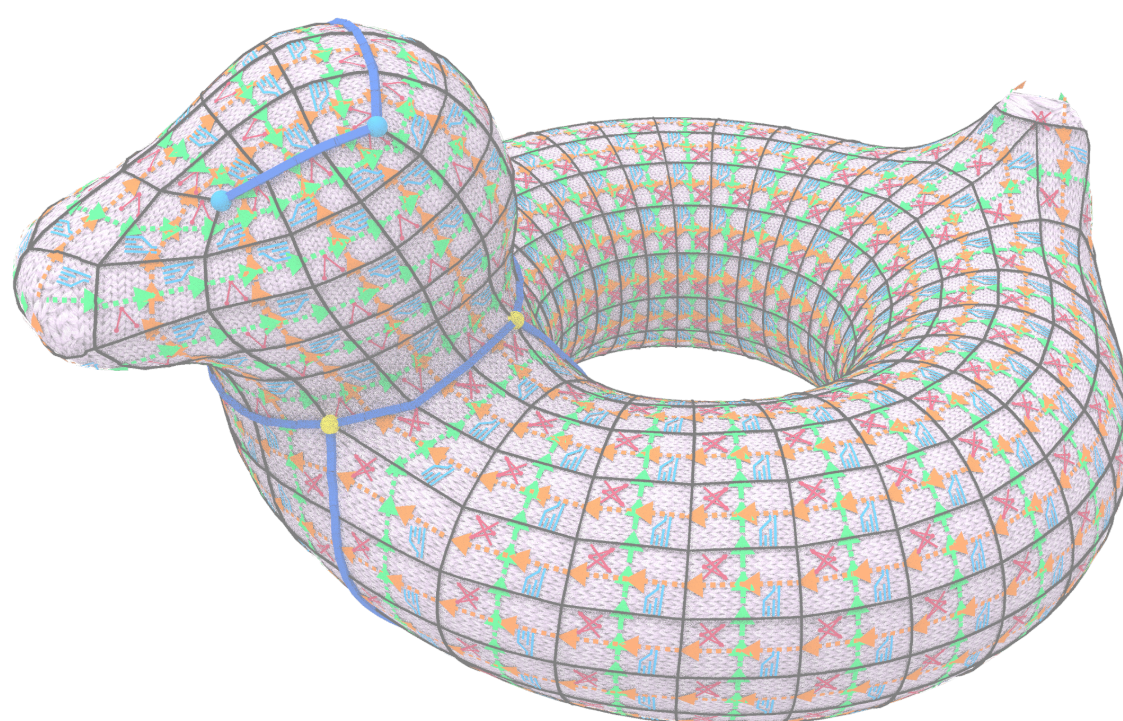


What we bring

State of the art



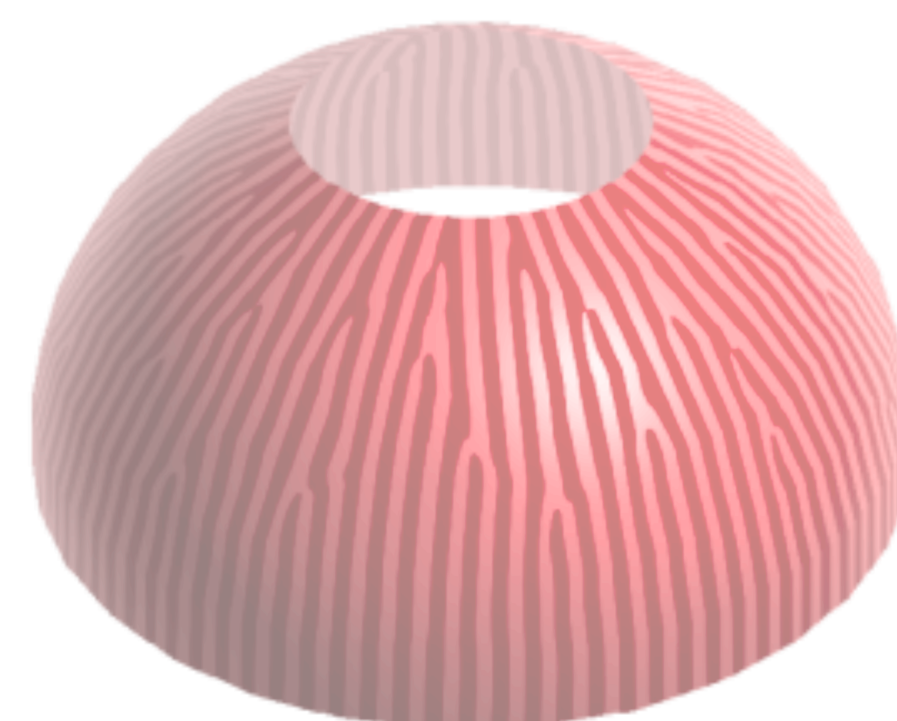
AutoKnit [Narayanan18]:
Not global, lack of user control



Knit Templates [Jones22]:
No stitch-level
singularity placement



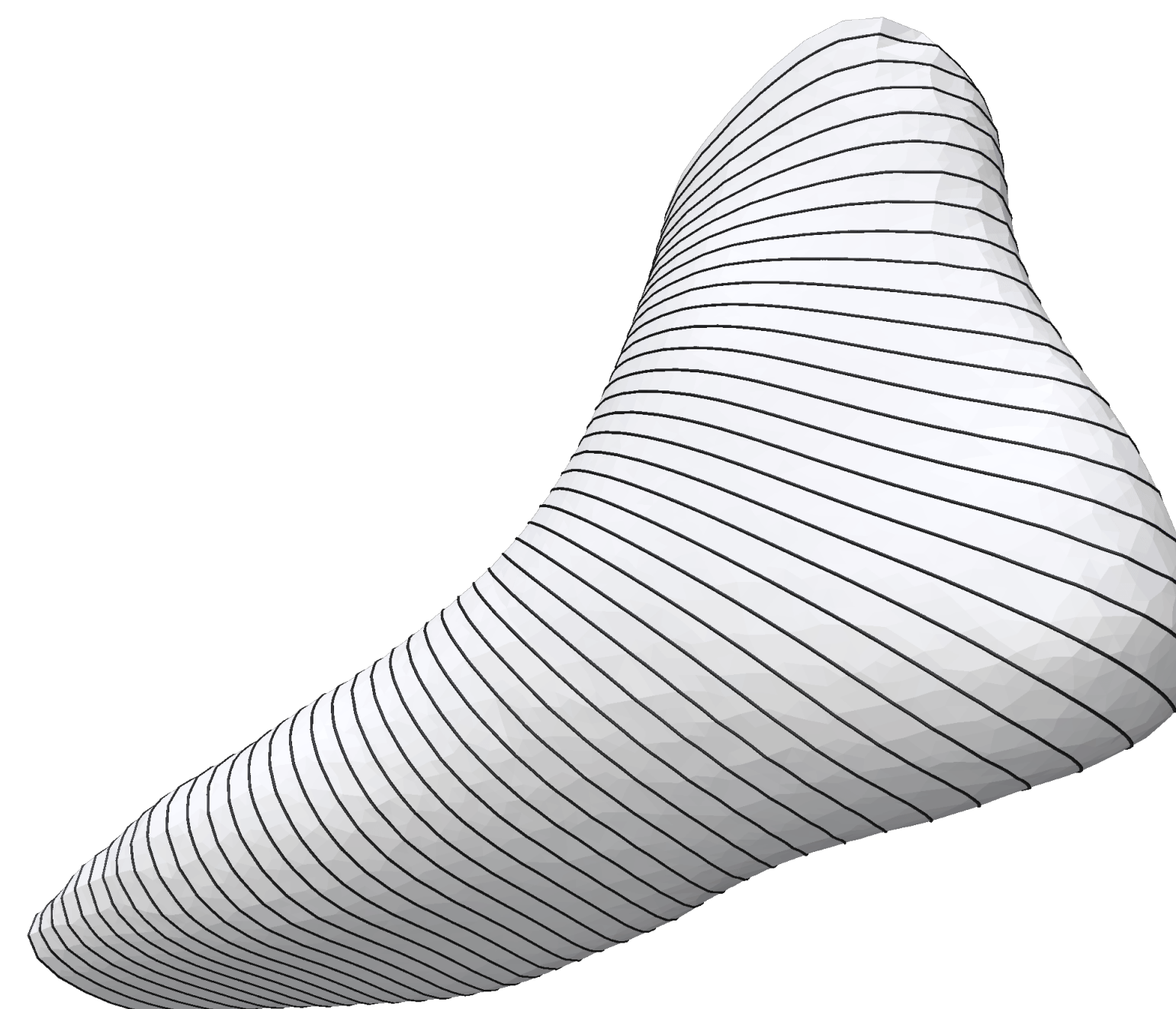
KnitKit [Nader21]:
No manufacturability
guarantee

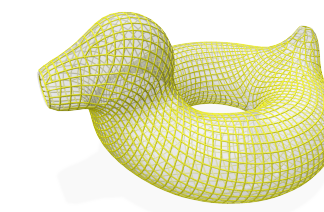


Helix-free Stripes [Mitra23]:
Costly mixed-integer solve

This paper

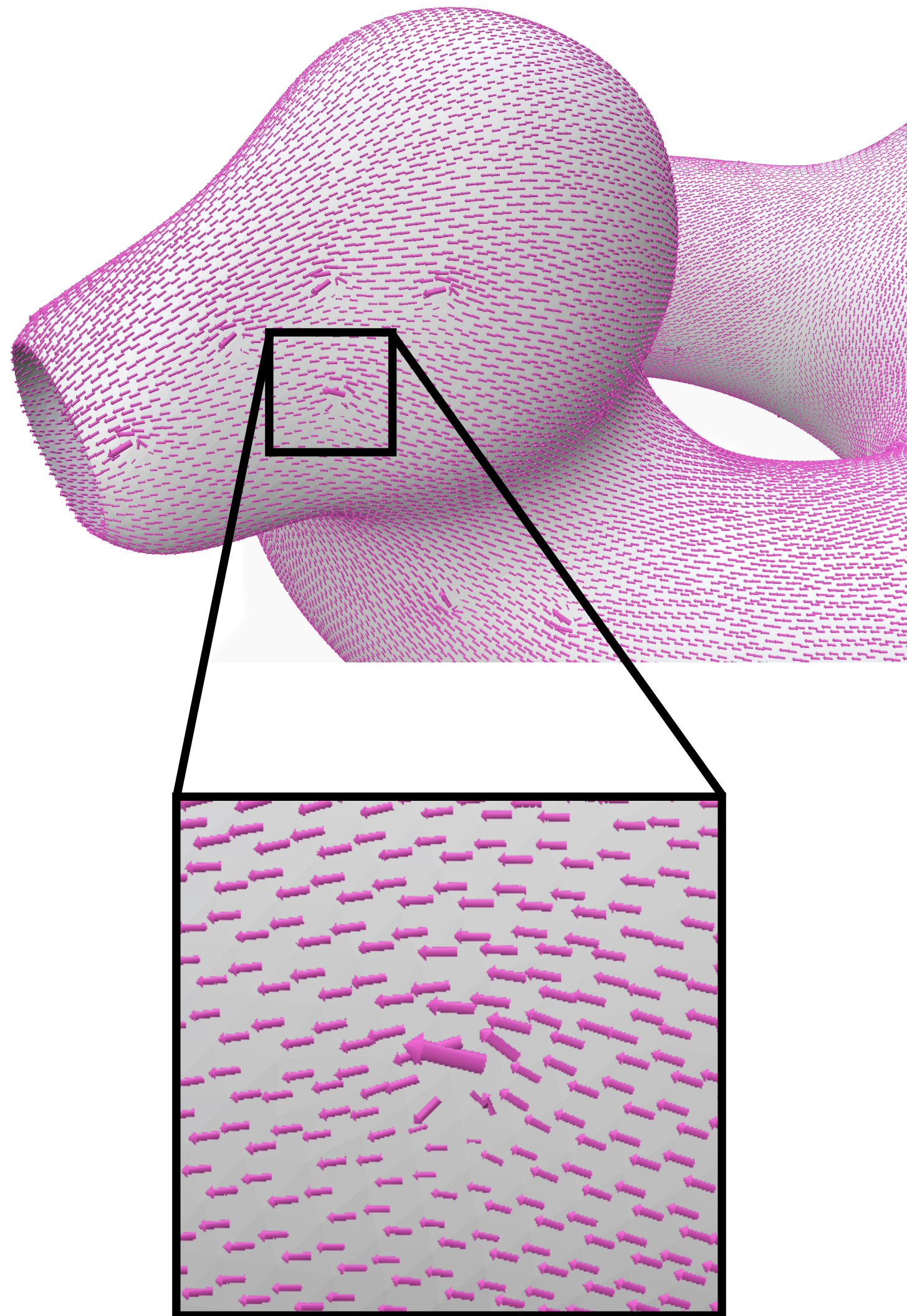
- ▶ **Fast** (greedy strategy)
- ▶ **Automatic** singularity placement
- ▶ With **flexible** user control



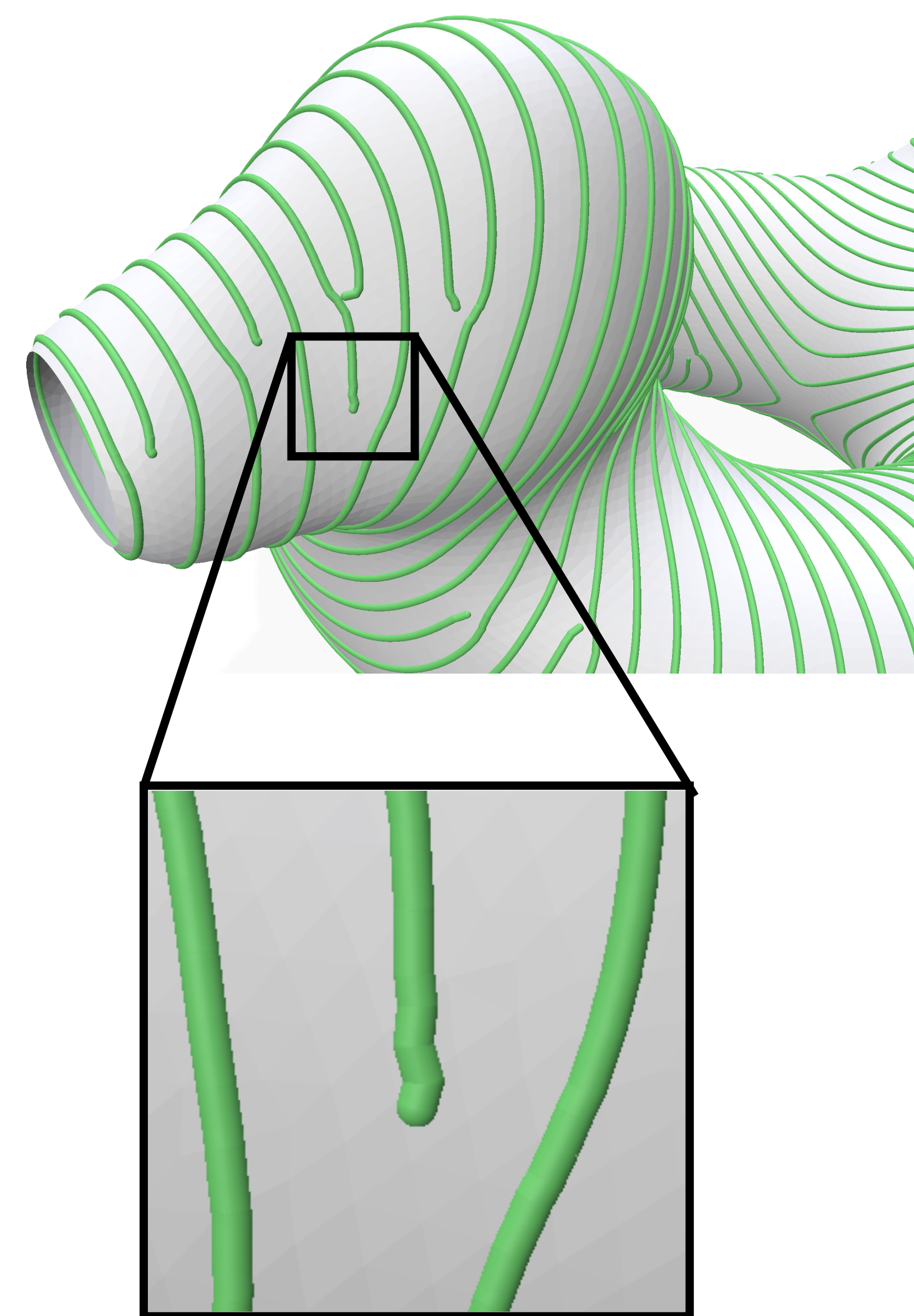


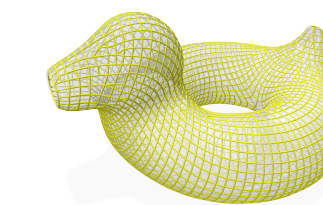
Computing stripe patterns

Singular vector fields



Stripes



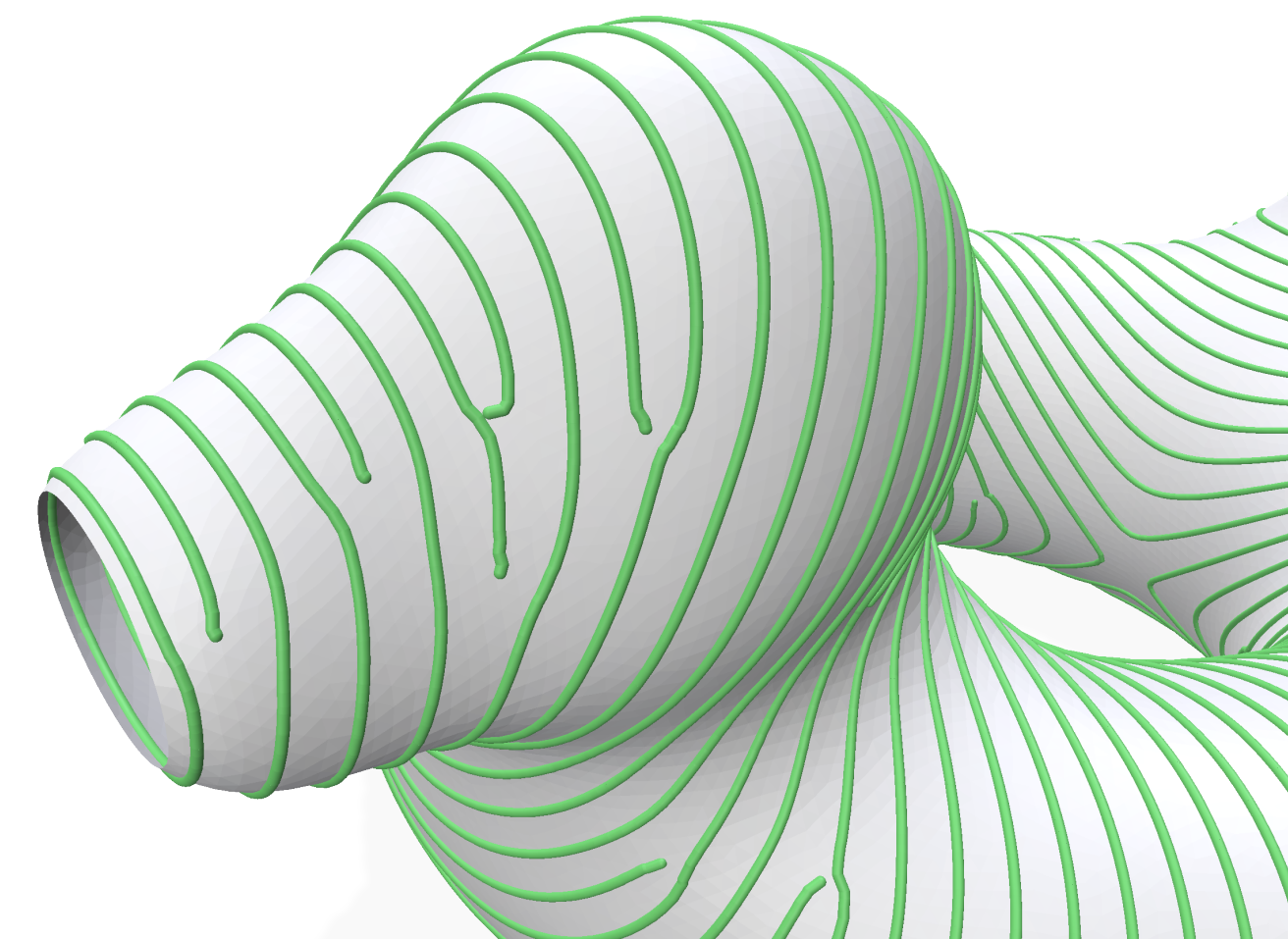
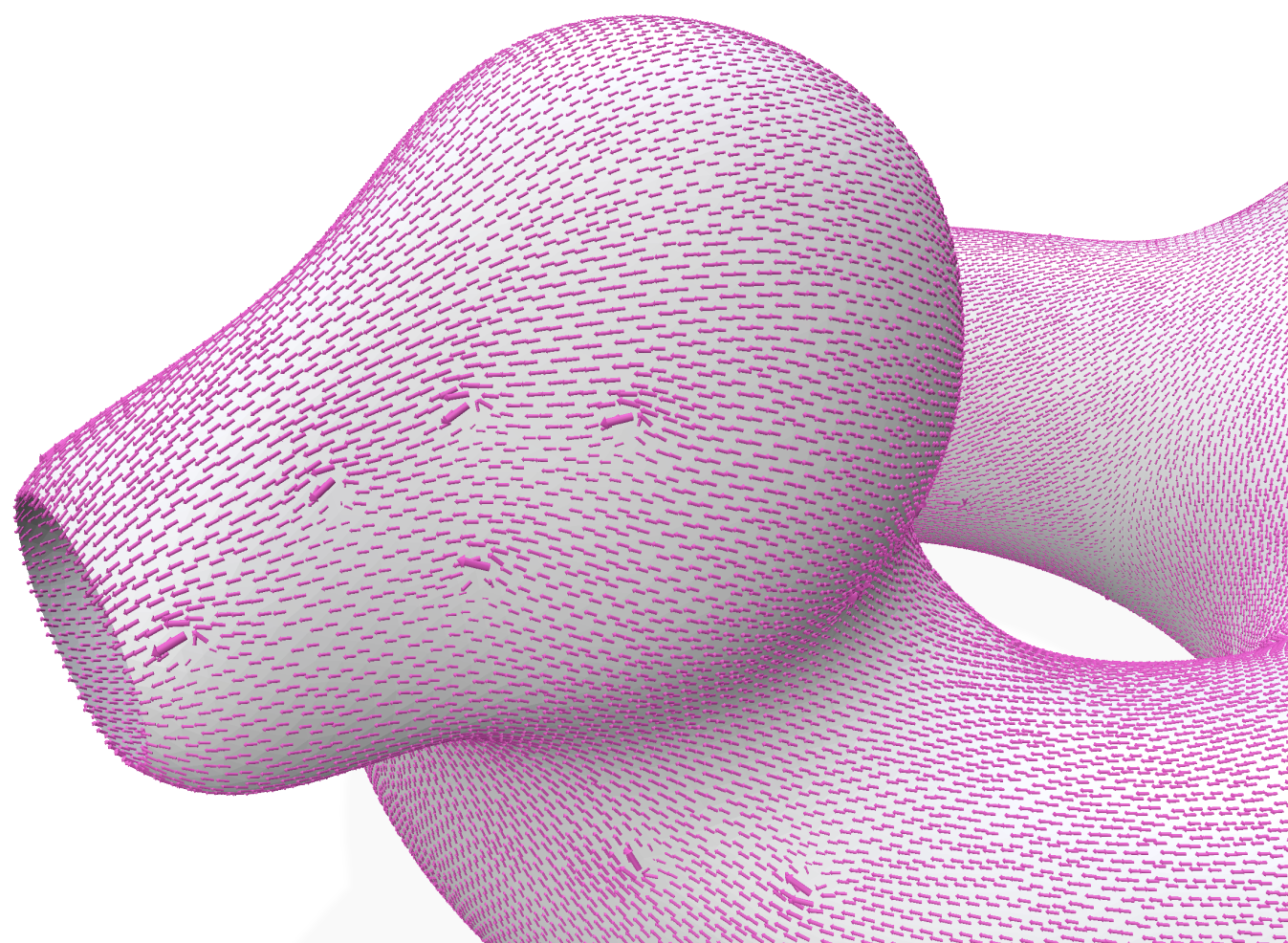


Computing stripe patterns

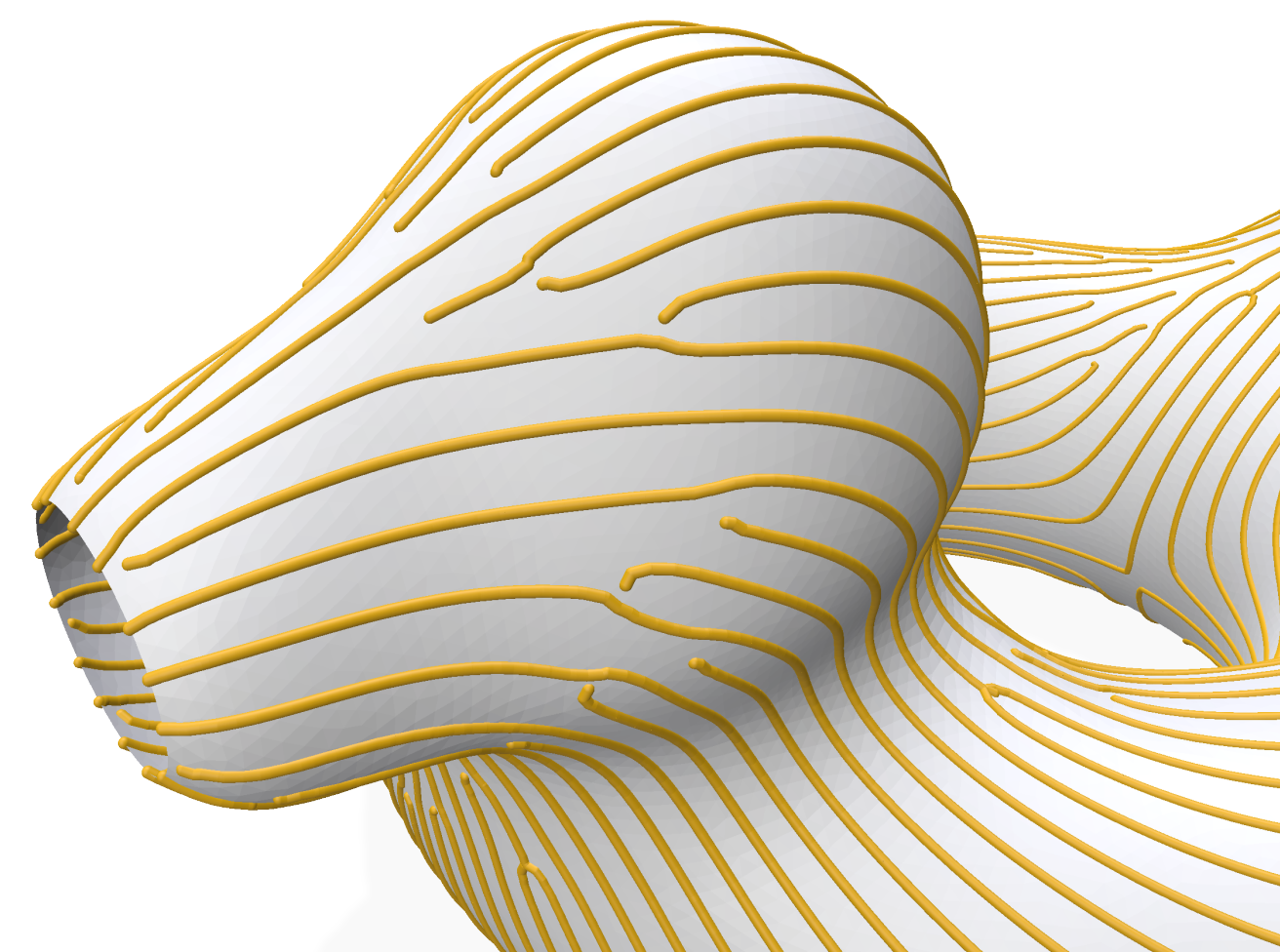
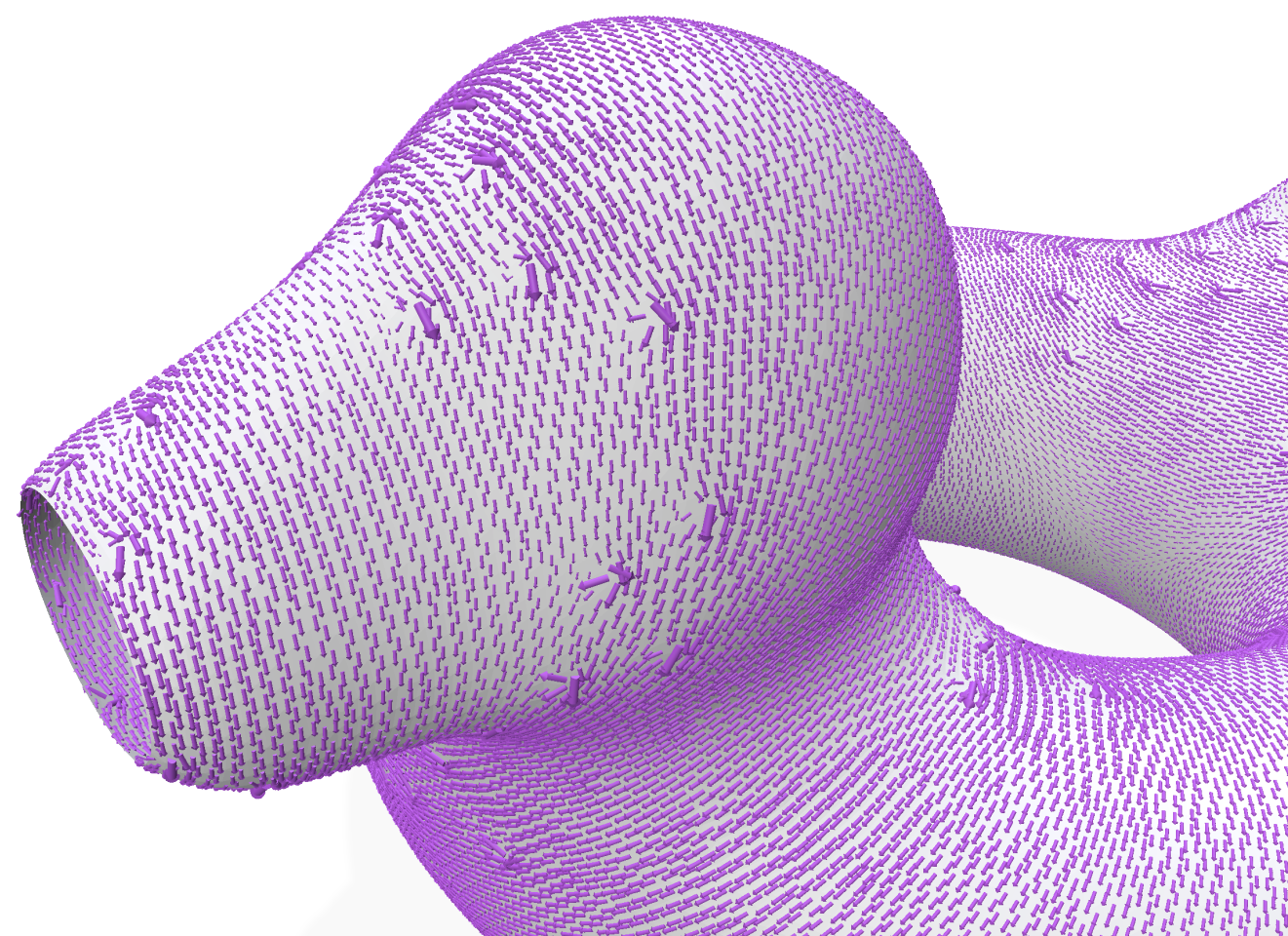
Singular vector fields

Stripes

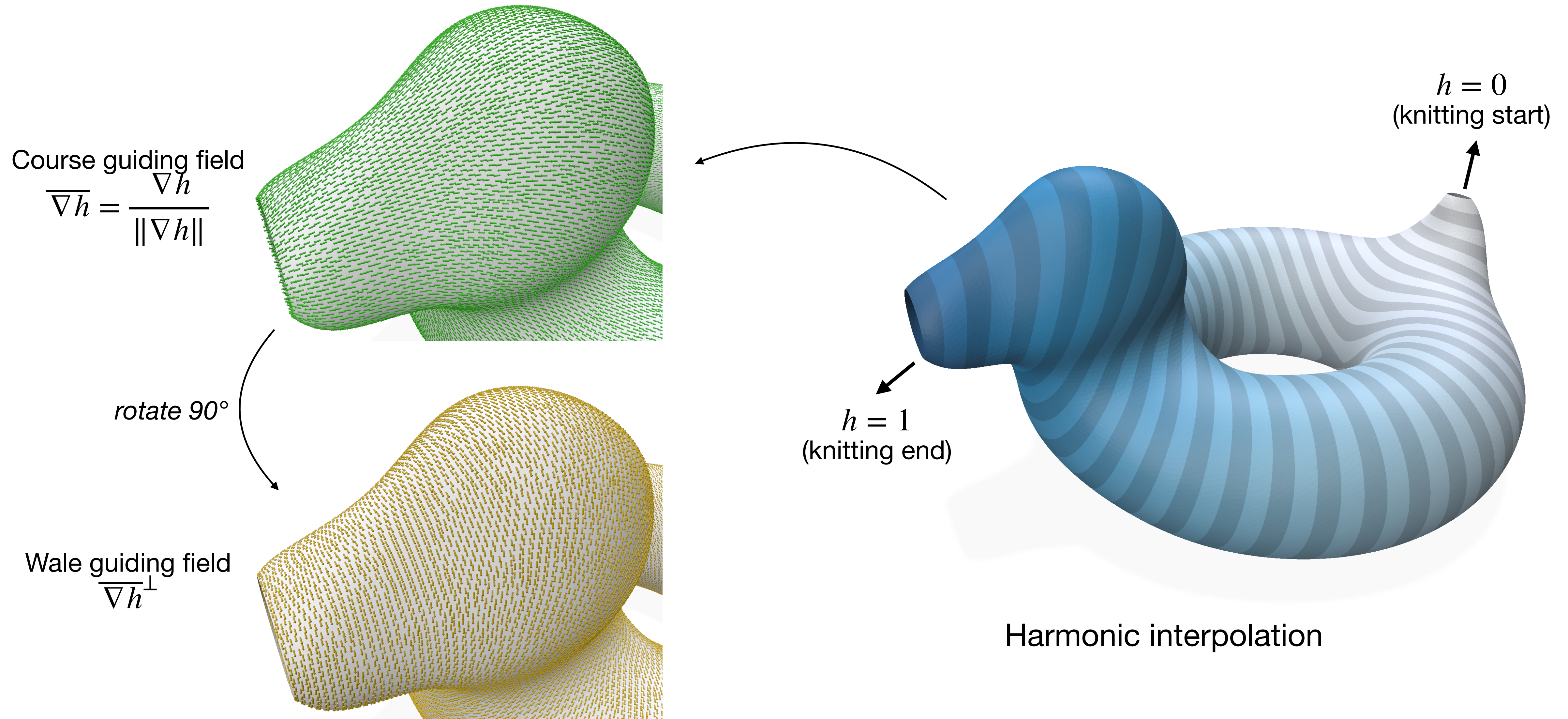
Course



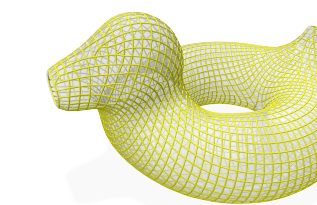
Wale



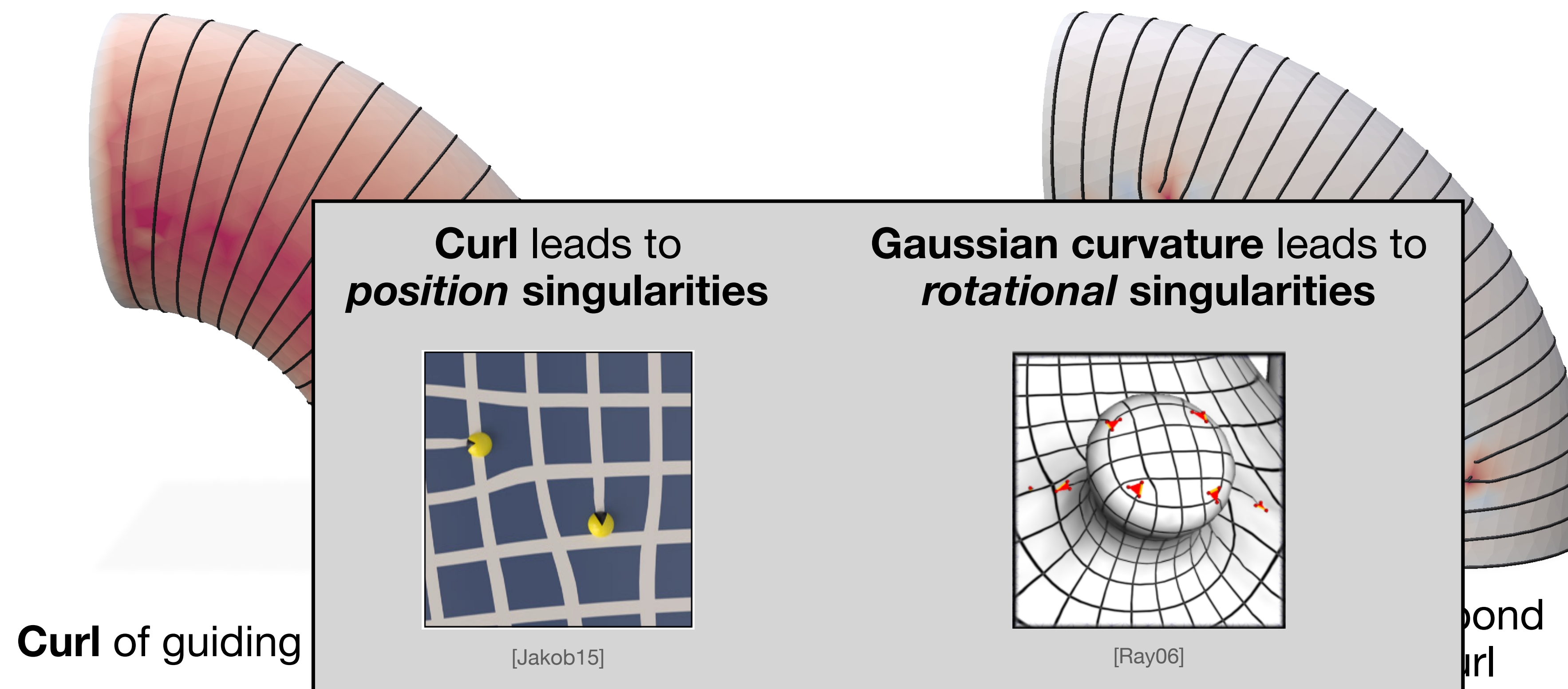
Knitting is guided by a *time function*



Vector fields are normalized to promote **knit graph regularity**

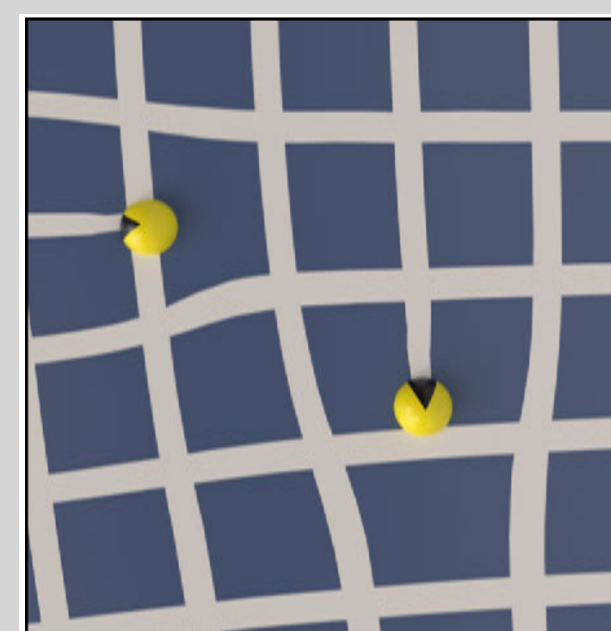


Curl signal



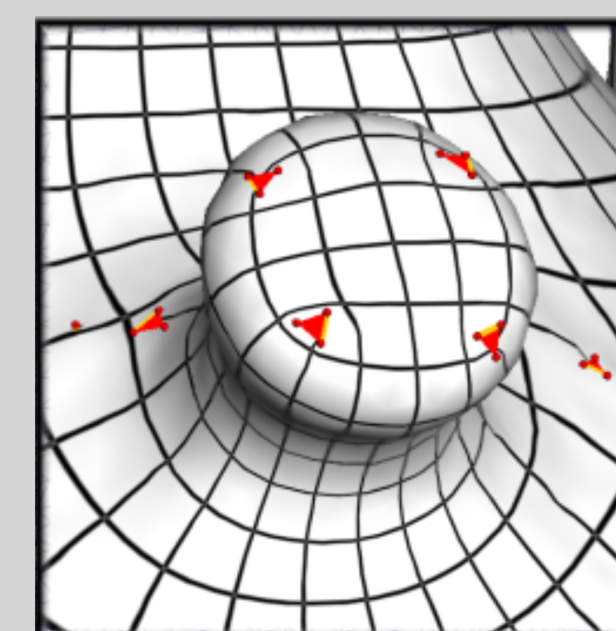
Curl of guiding

Curl leads to
position singularities



[Jakob15]

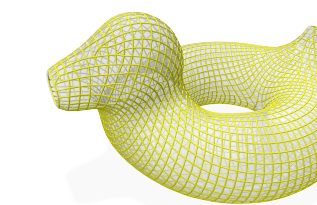
Gaussian curvature leads to
rotational singularities



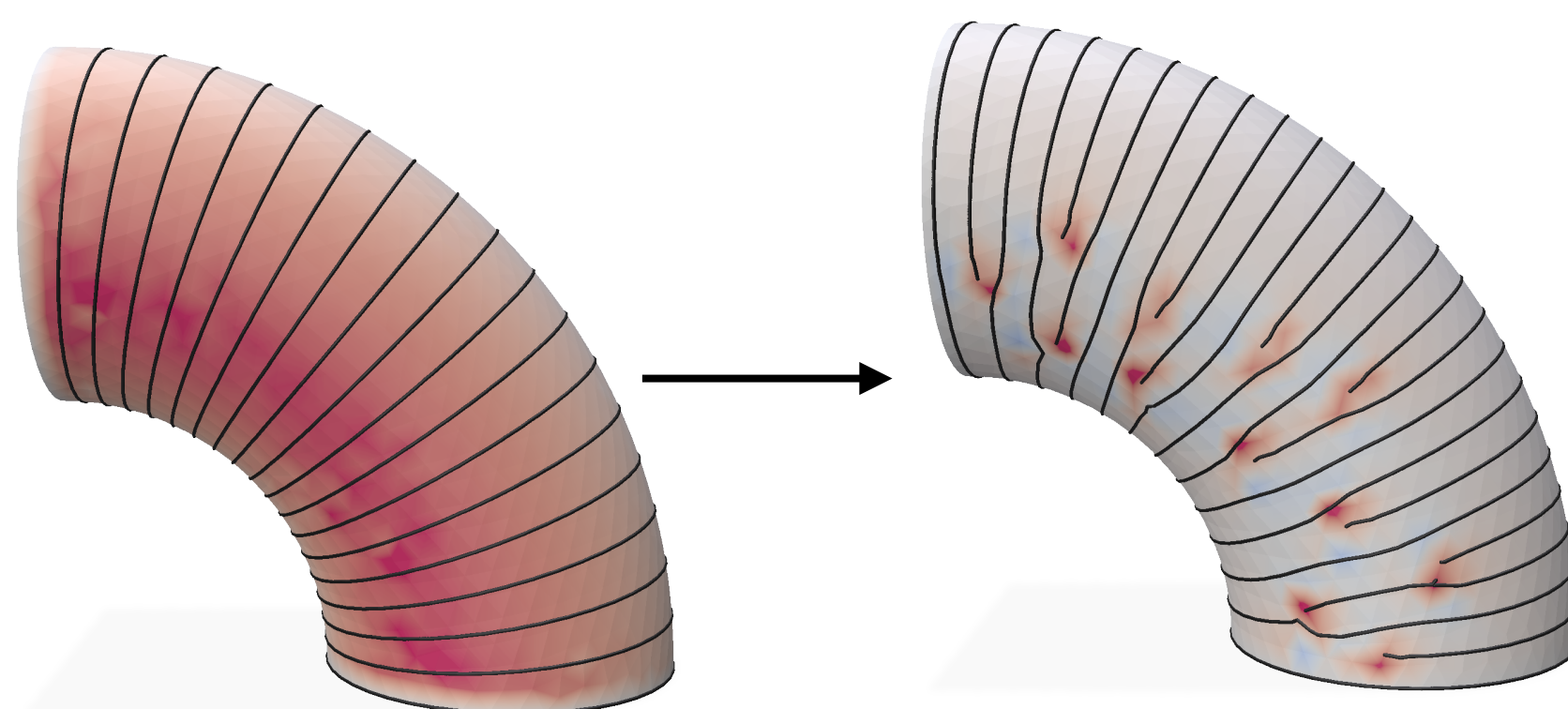
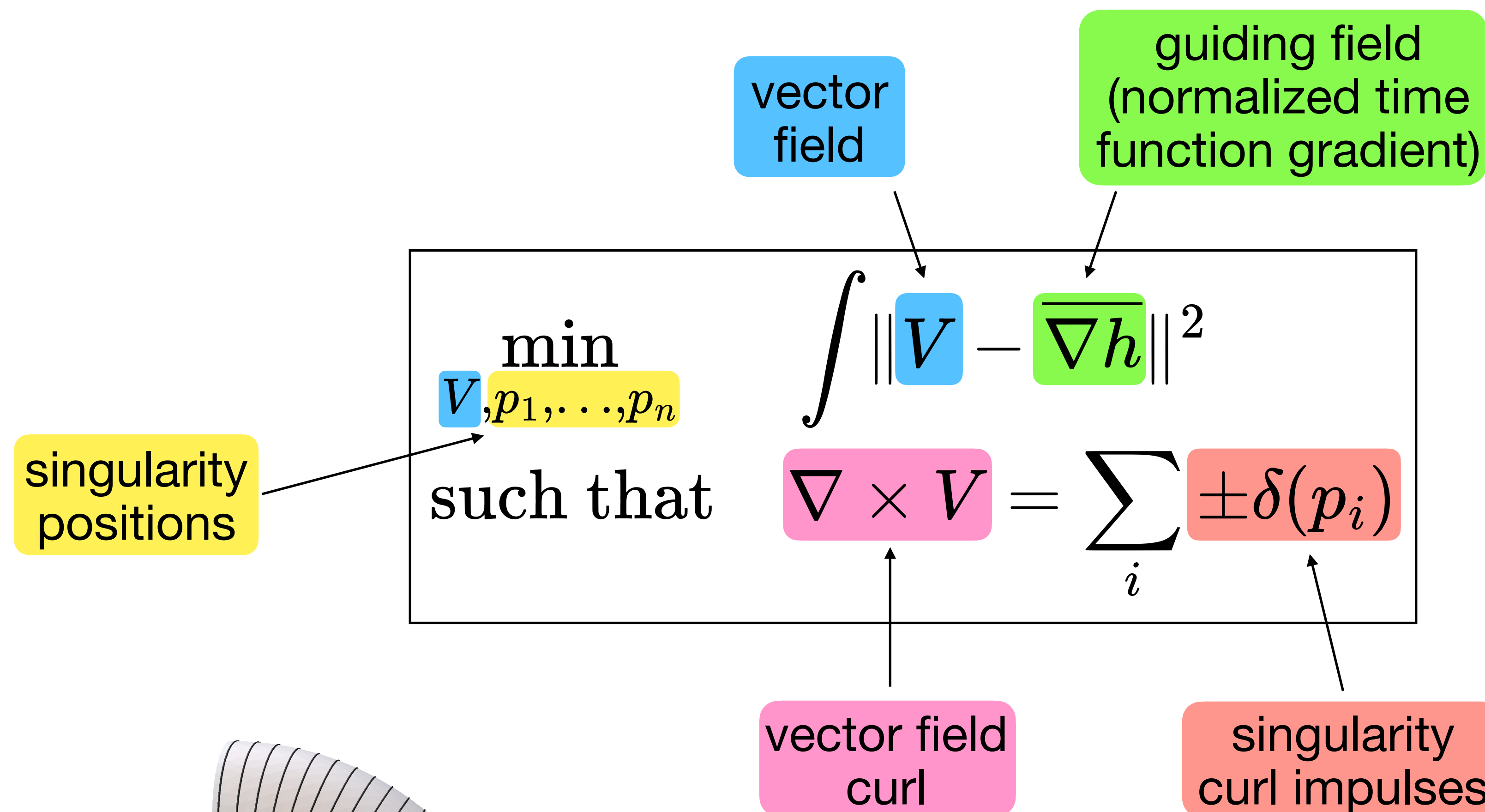
[Ray06]

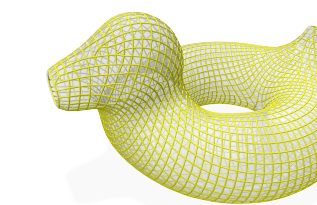
pond
curl

- Curl indicates where level set spacing **changes quickly**
- Inserting **singularities** allows for more **even spacing**
- Idea: *Quantize* curl to a discrete set of singularities, and use curl of $\overline{\nabla h}$ as a heuristic for placement!



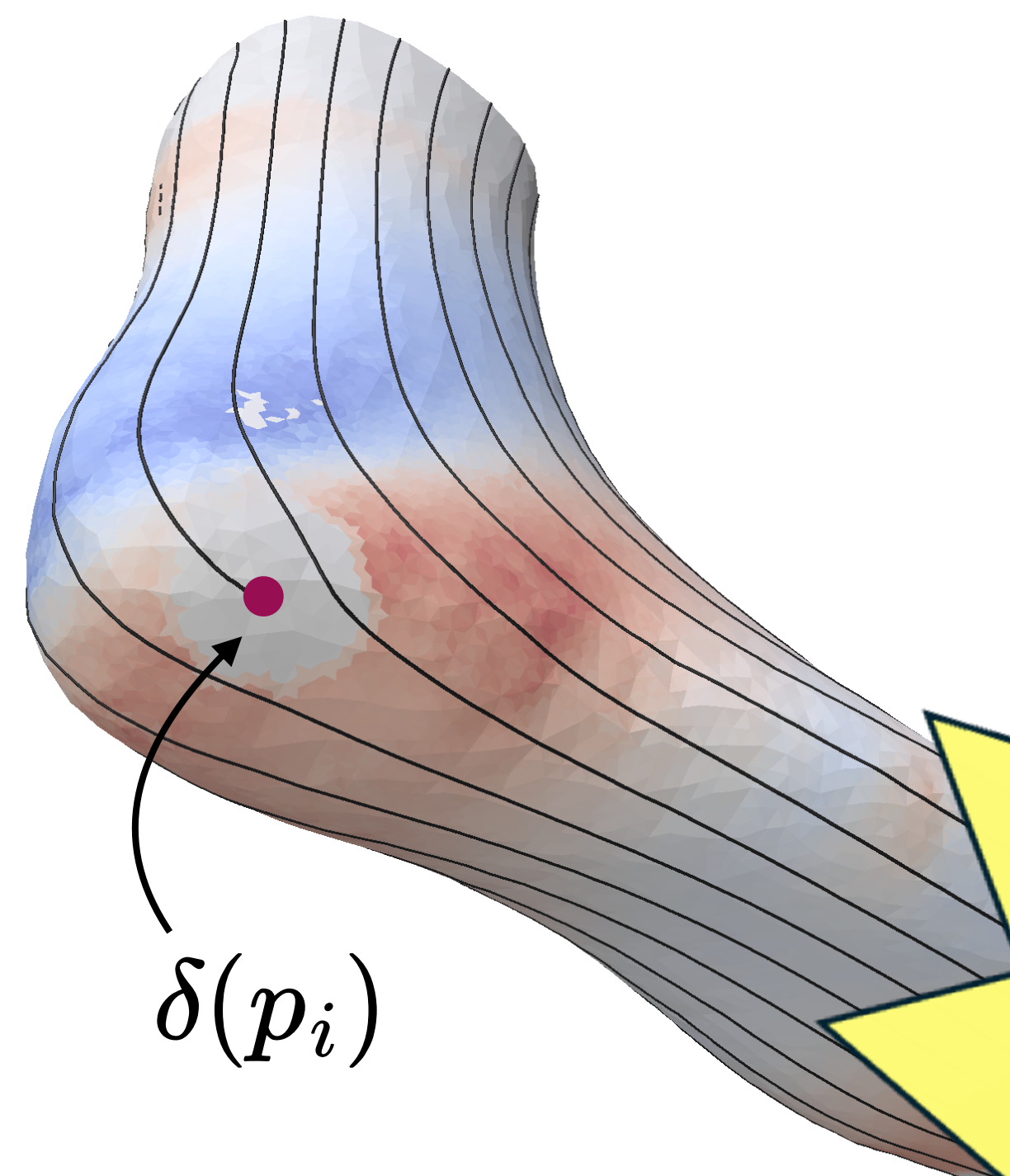
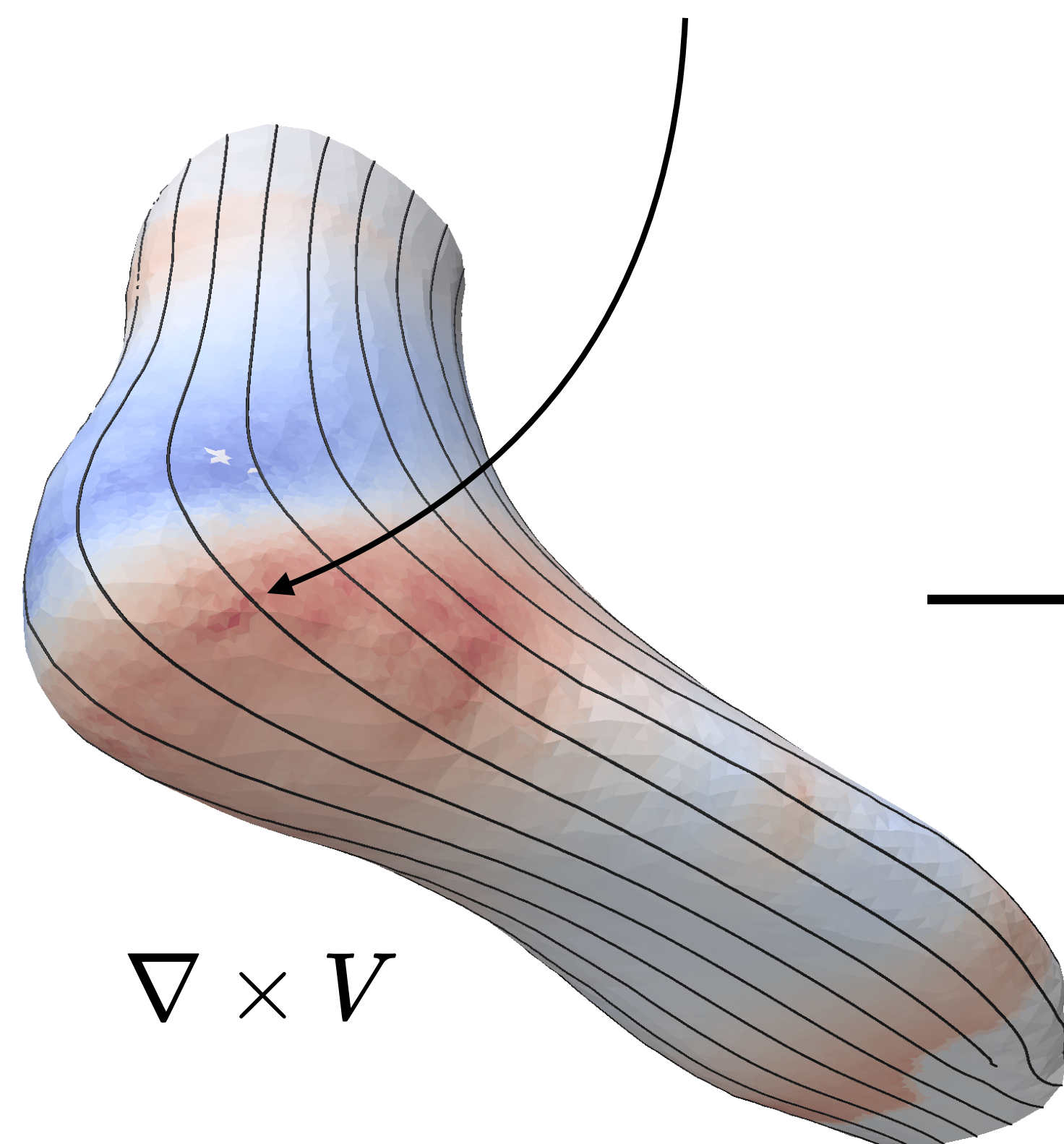
Curl quantization





Singularity placement strategy

Insert singularity at point
of max absolute curl

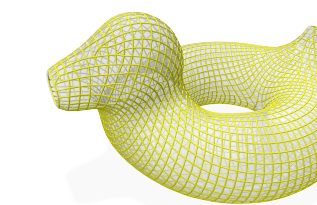


Repeat until objective

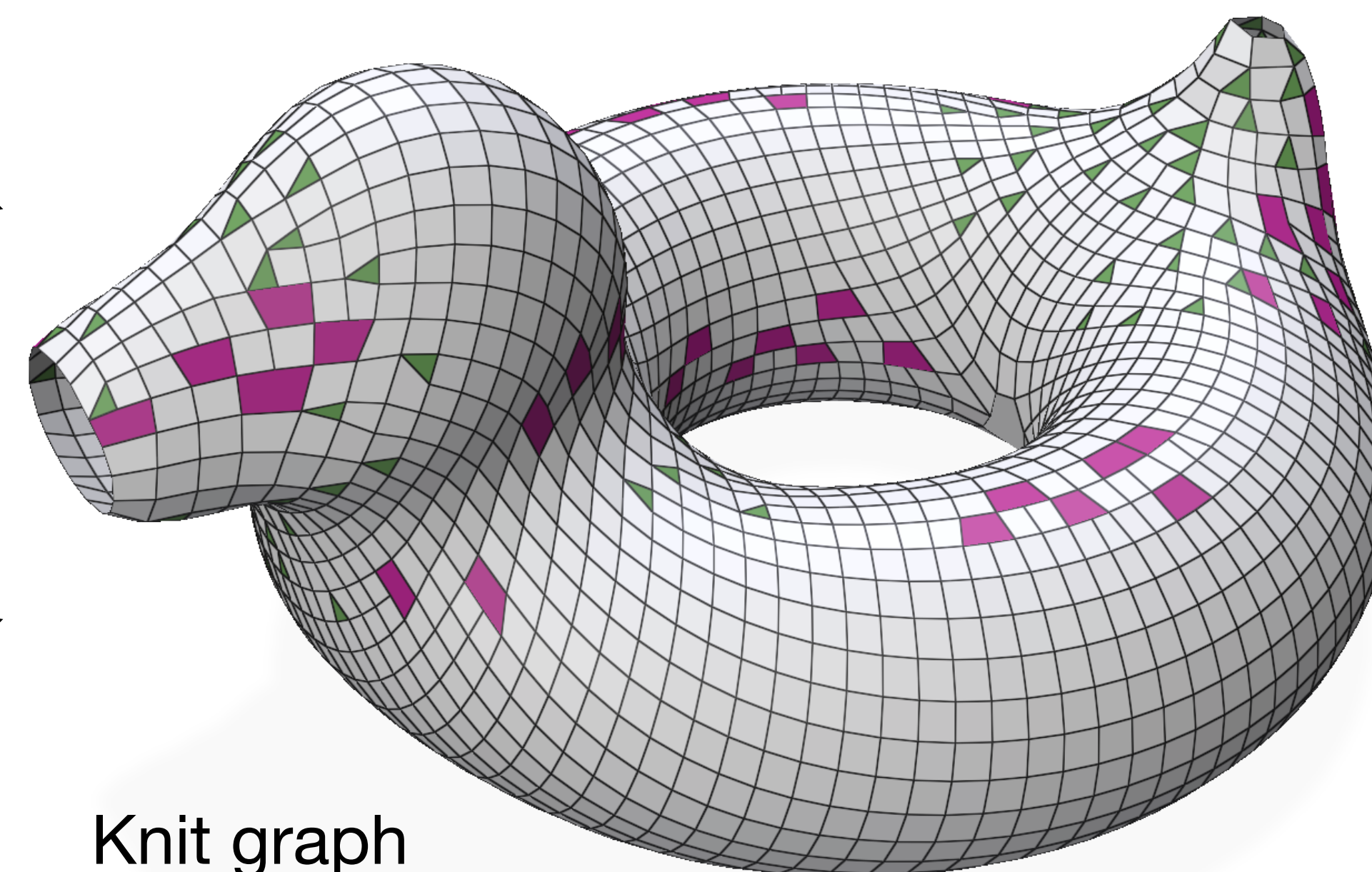
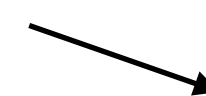
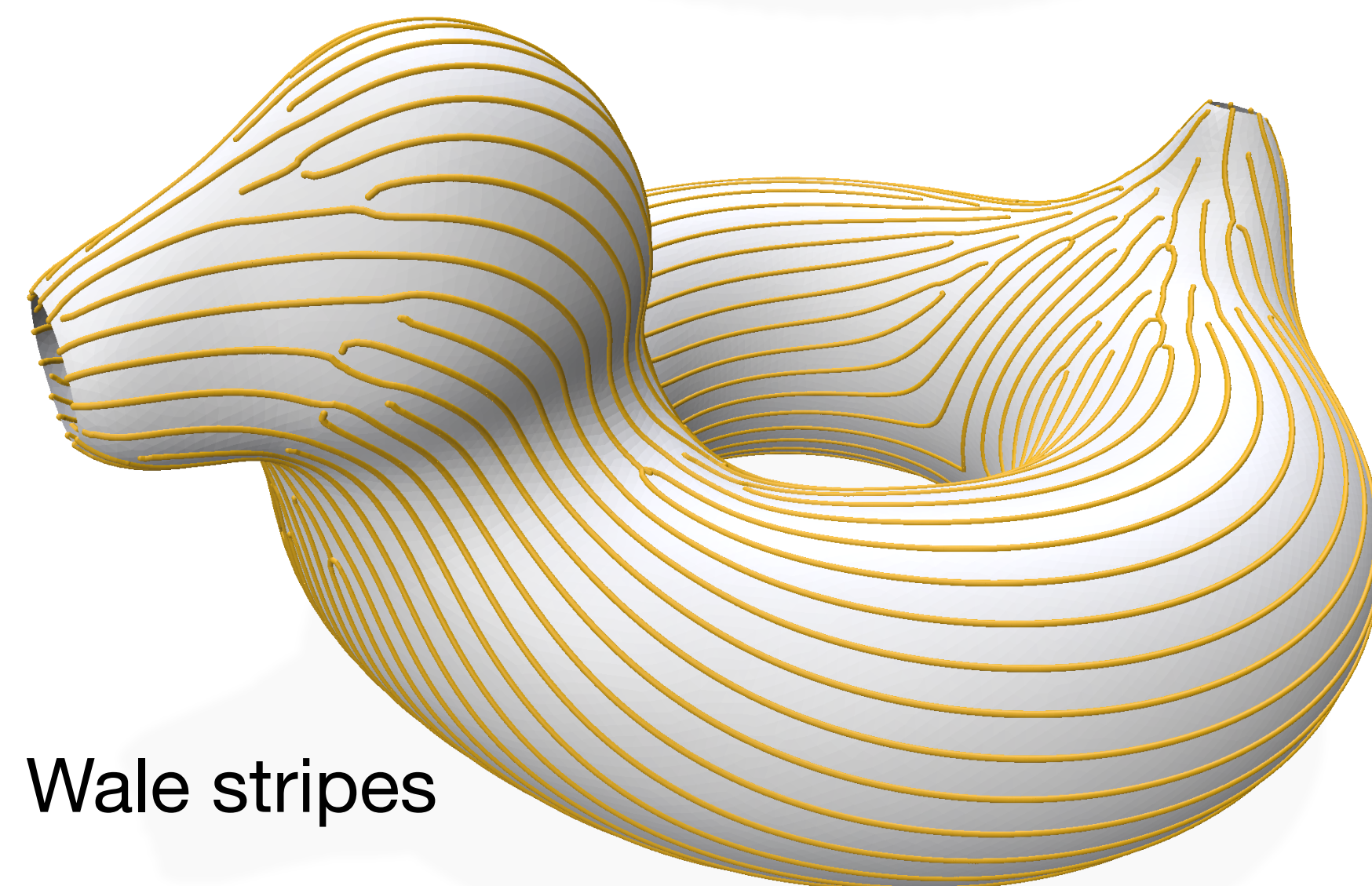
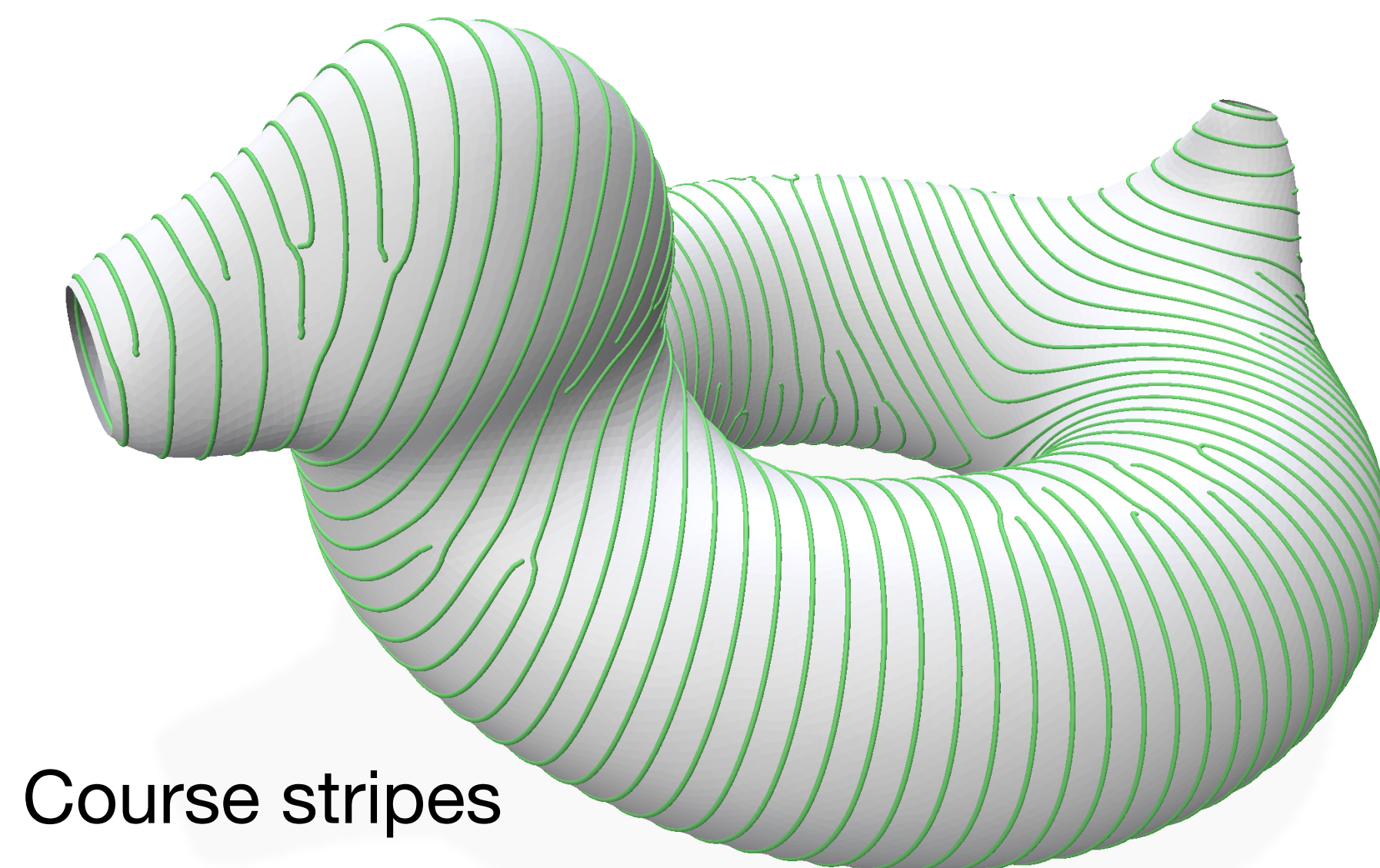
$$\int \|V - \overline{\nabla h}\|^2$$

stops decreasing

Course stripes
guaranteed helix-free
via [Mitra24]!

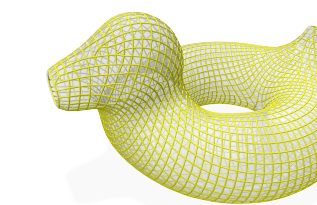


Knit graph construction

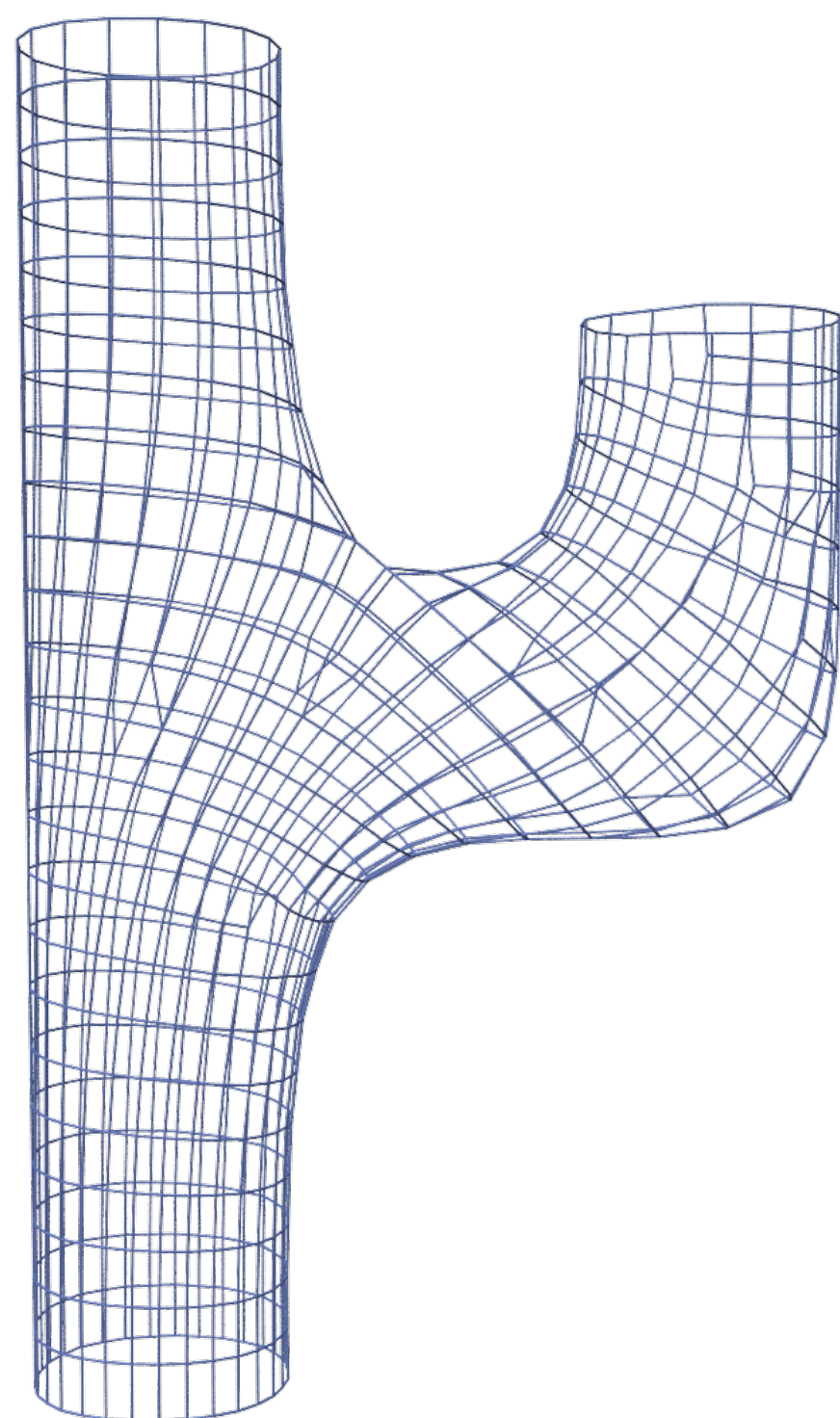


Pentagons = short row ends

Triangles = wale increases and decreases

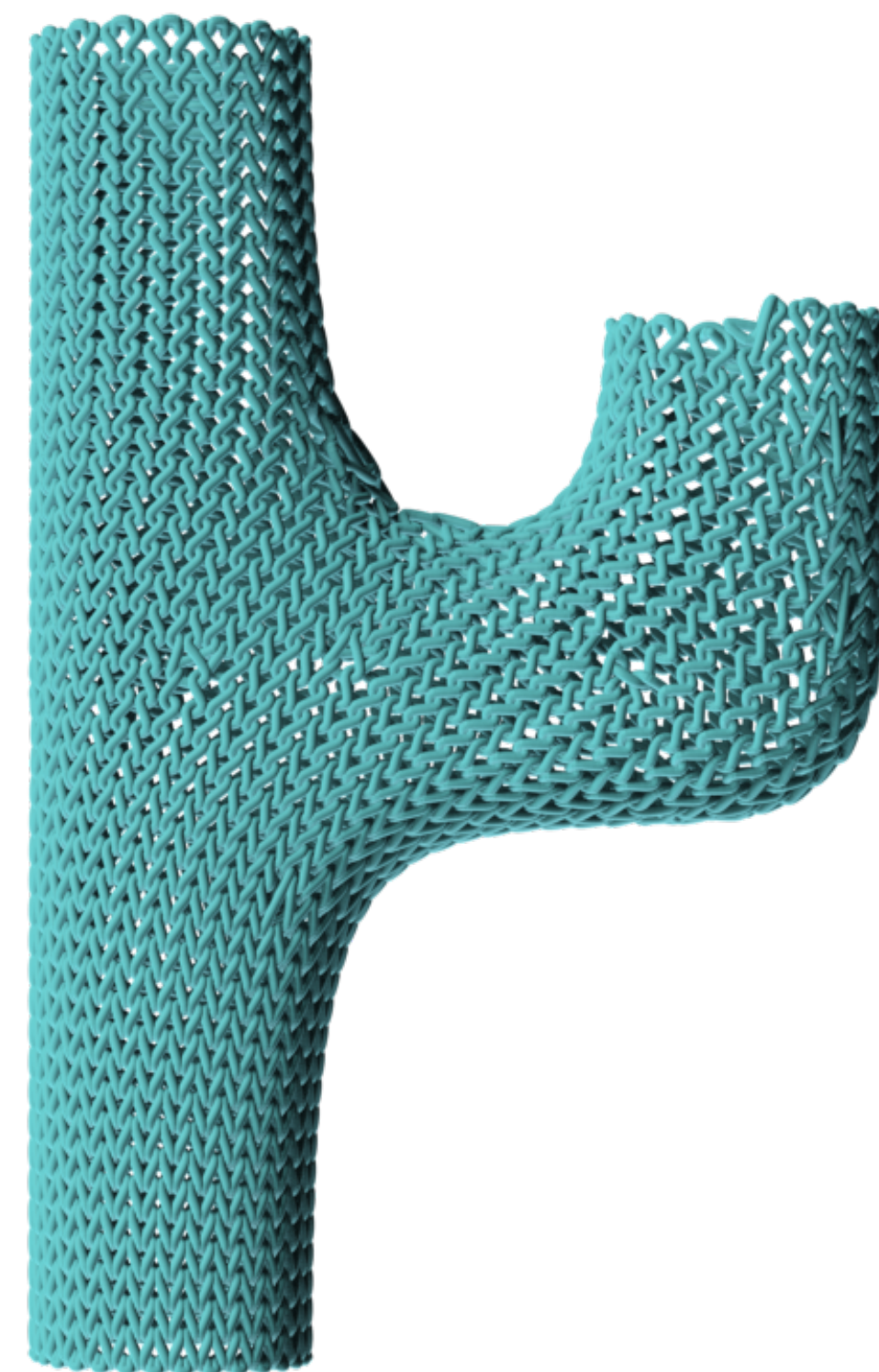


Results



Knit graphs

- Machine-knittable



Yarn-level renders

- Renders are smooth without any yarn relaxation!



Machine knits

- Scheduling done with AutoKnit

compared to
[Mitra23]

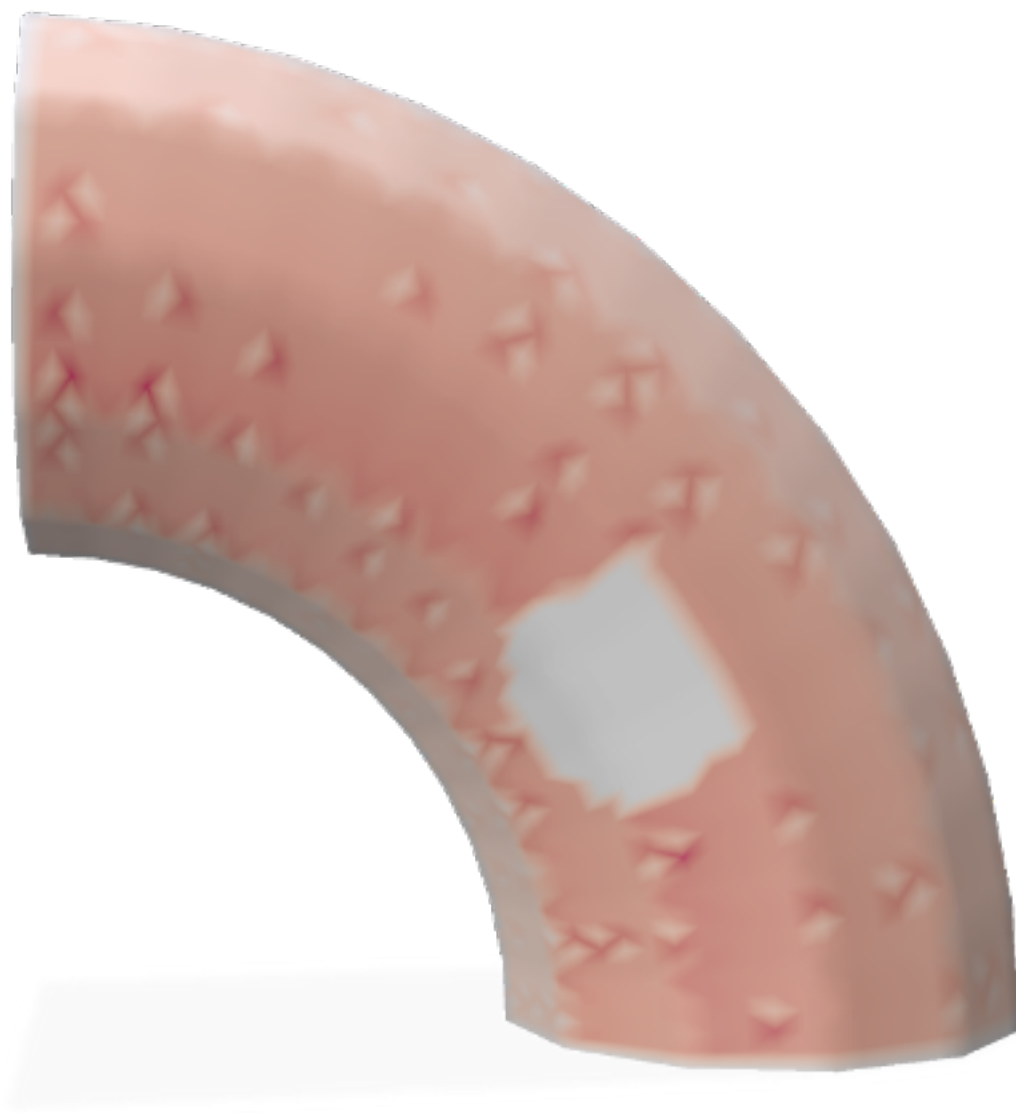


Model	#V	#F	Time	Speedup
Sock	279	538	< 1 s	53x
Glove	37.5k	74.5k	56 s	timeout
Cactus	391	736	< 1 s	100x
Dress	8.6k	17k	11.5 s	31x
4-panel skirt	1.1k	1.9k	< 1 s	no cut&sew
Pants	1.2k	2k	< 1 s	no cut&sew

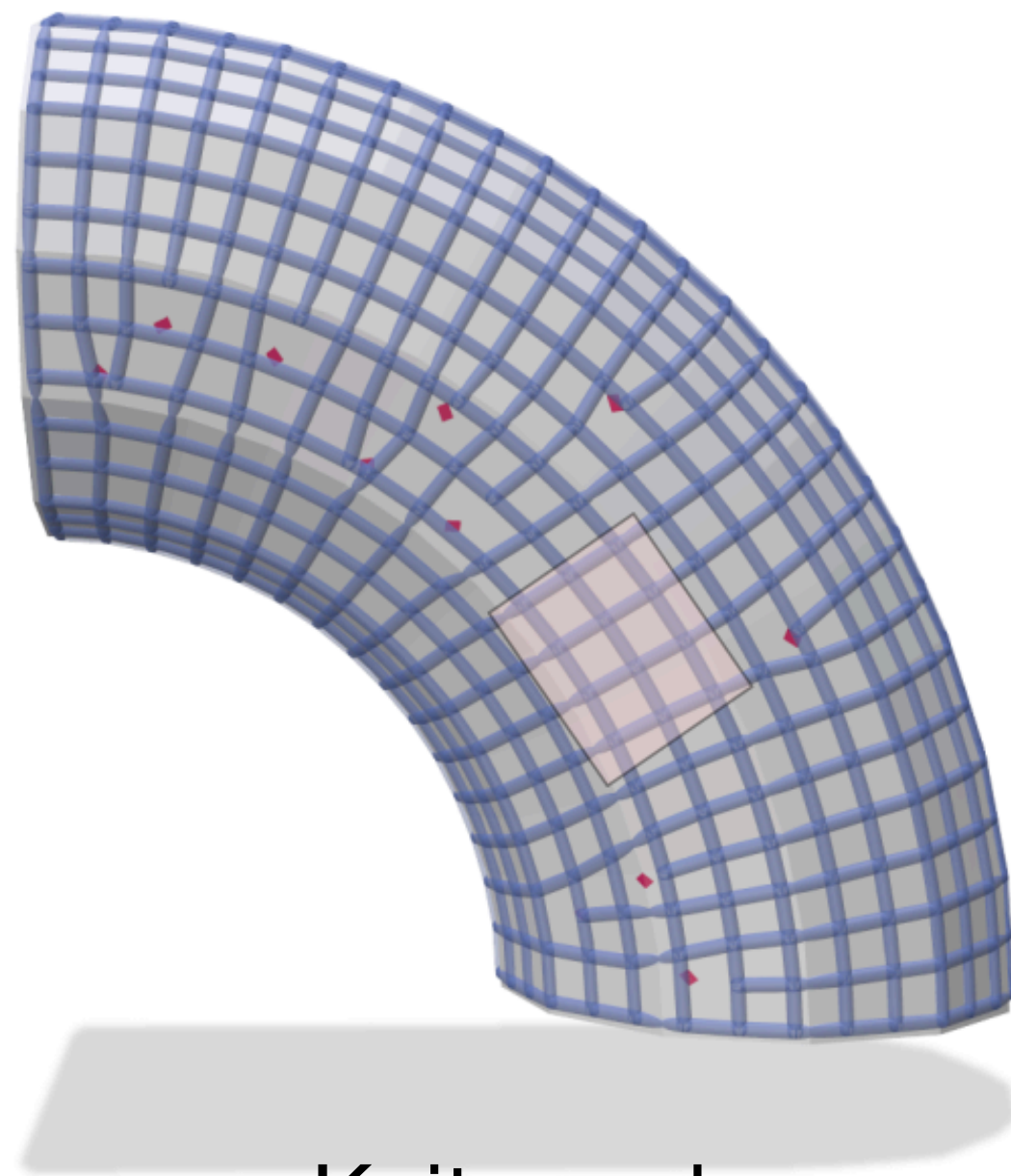
User has control over singularity placement

through **curl signal editing**

Prevent singularities in specified region
by **masking** the curl signal

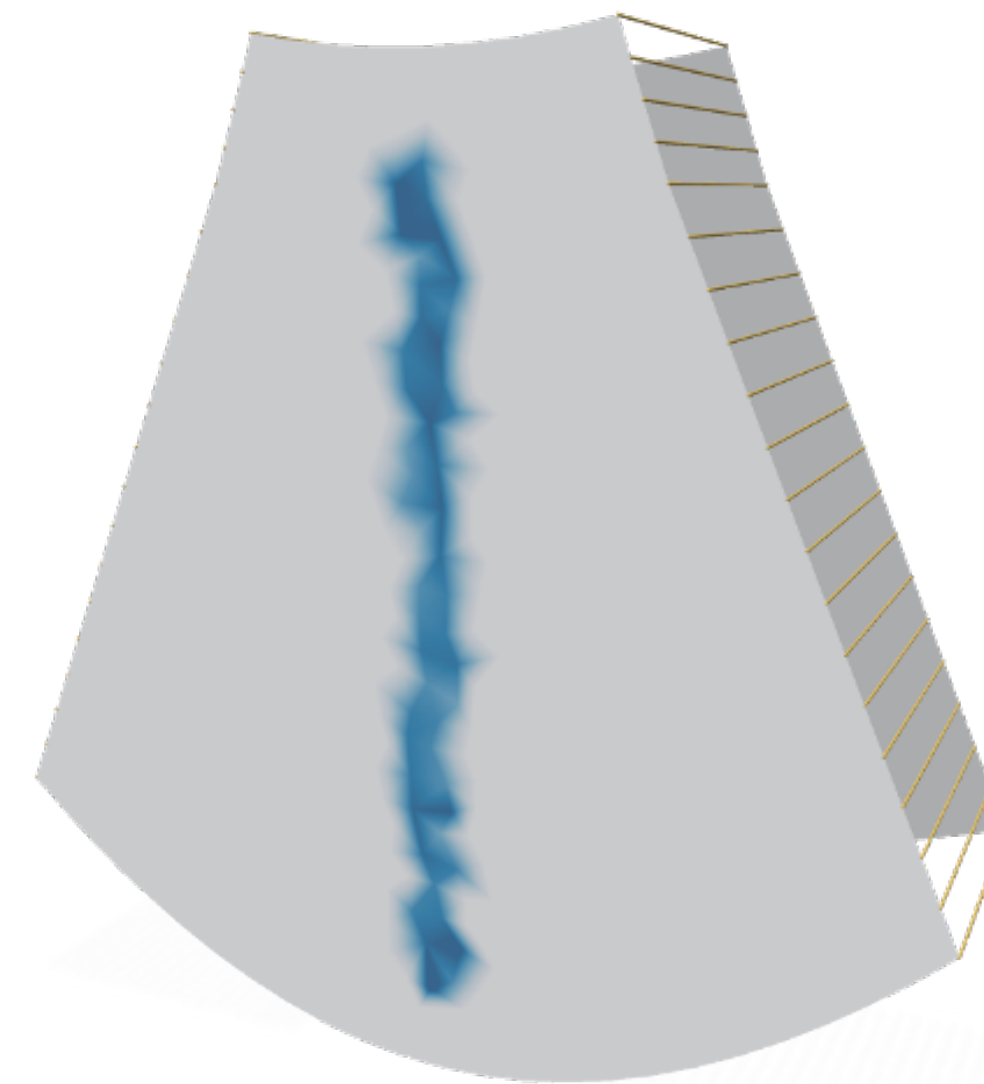


Curl signal

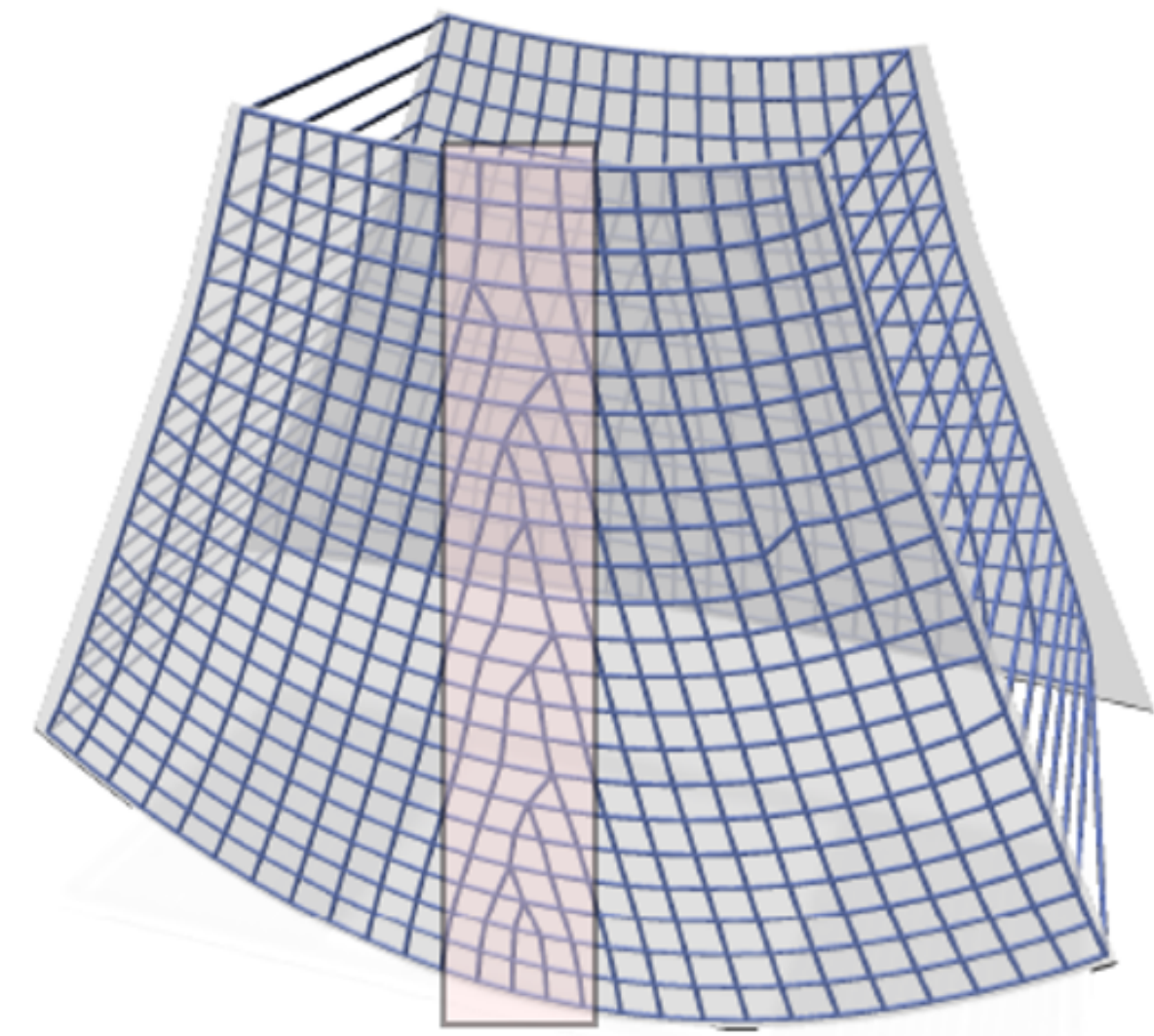


Knit graph

Create **seam** in specified region
by **boosting** the curl signal

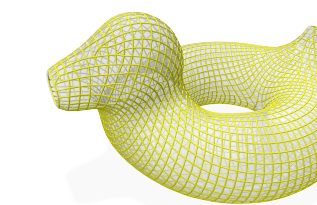


Curl signal



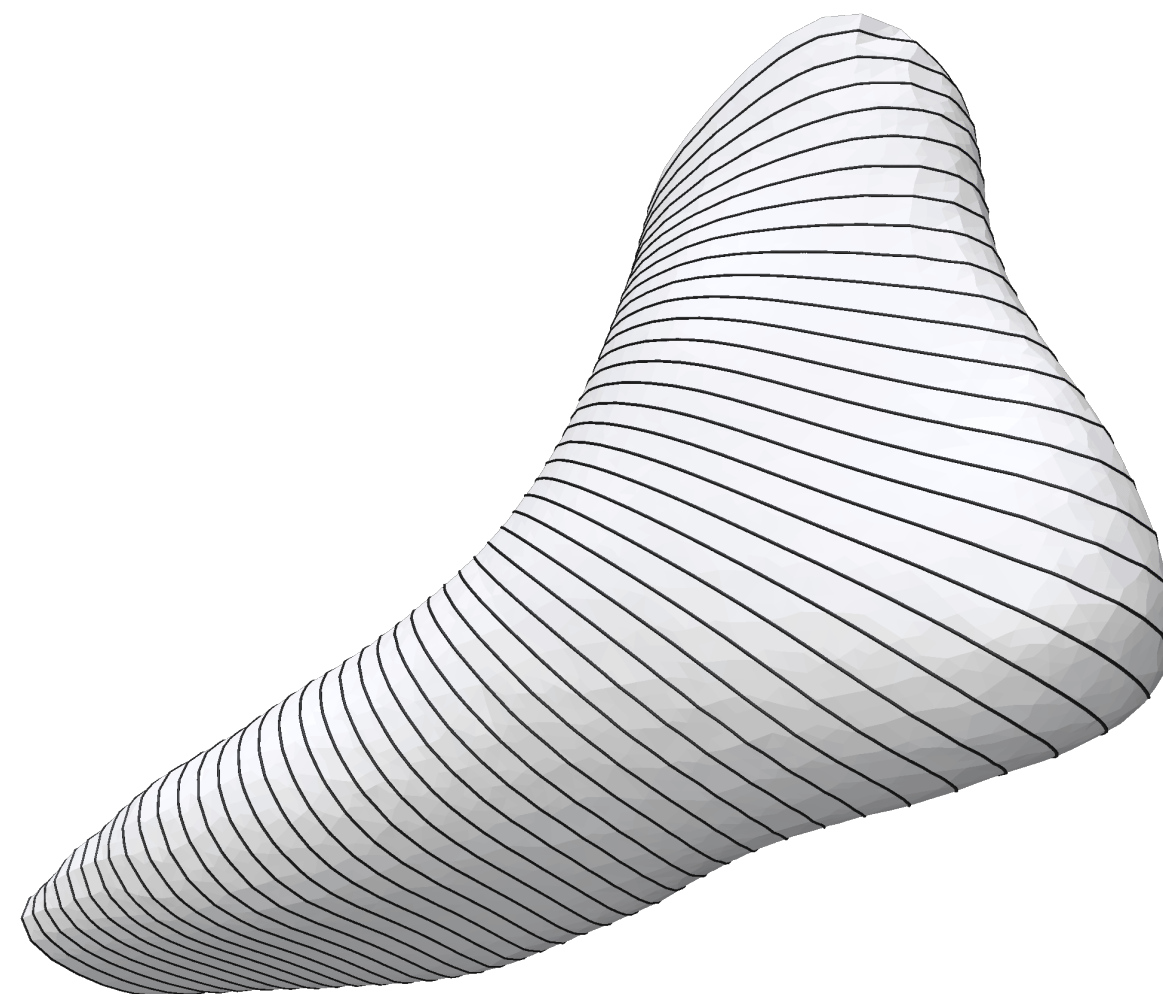
Knit graph

Not possible in previous works!



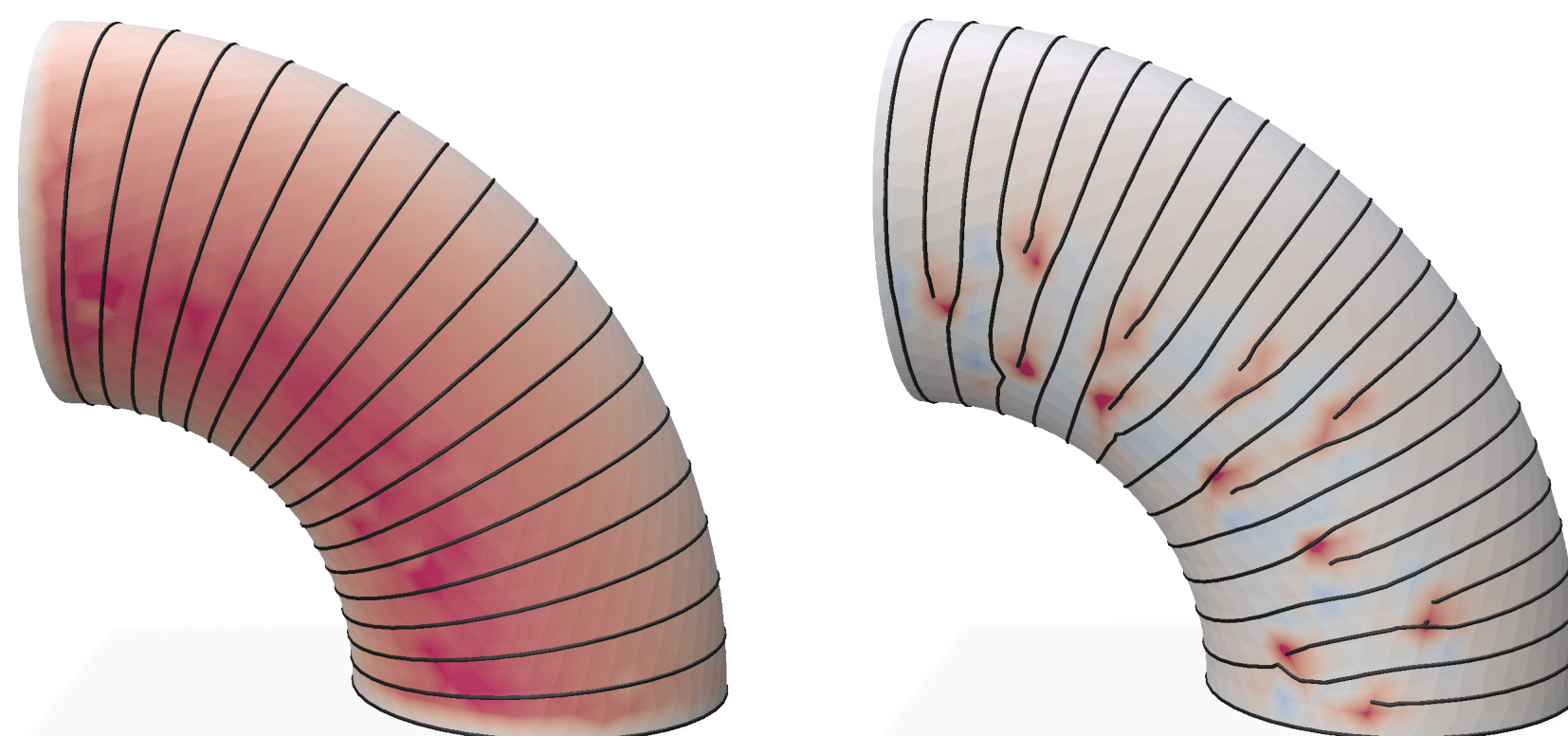
Conclusion

Fast, Automatic, Flexible
placement of knit singularities



Key idea:

Curl indicates where to place singularities



Coming up:

- ▶ Global strategy: place all singularities in one optimization
- ▶ Design better guiding fields, or optimize guiding field and knit graph jointly

