Cloth Compression Using Local Cylindrical Coordinates

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Motivation

- Realistic cloth simulation is tedious and time-consuming

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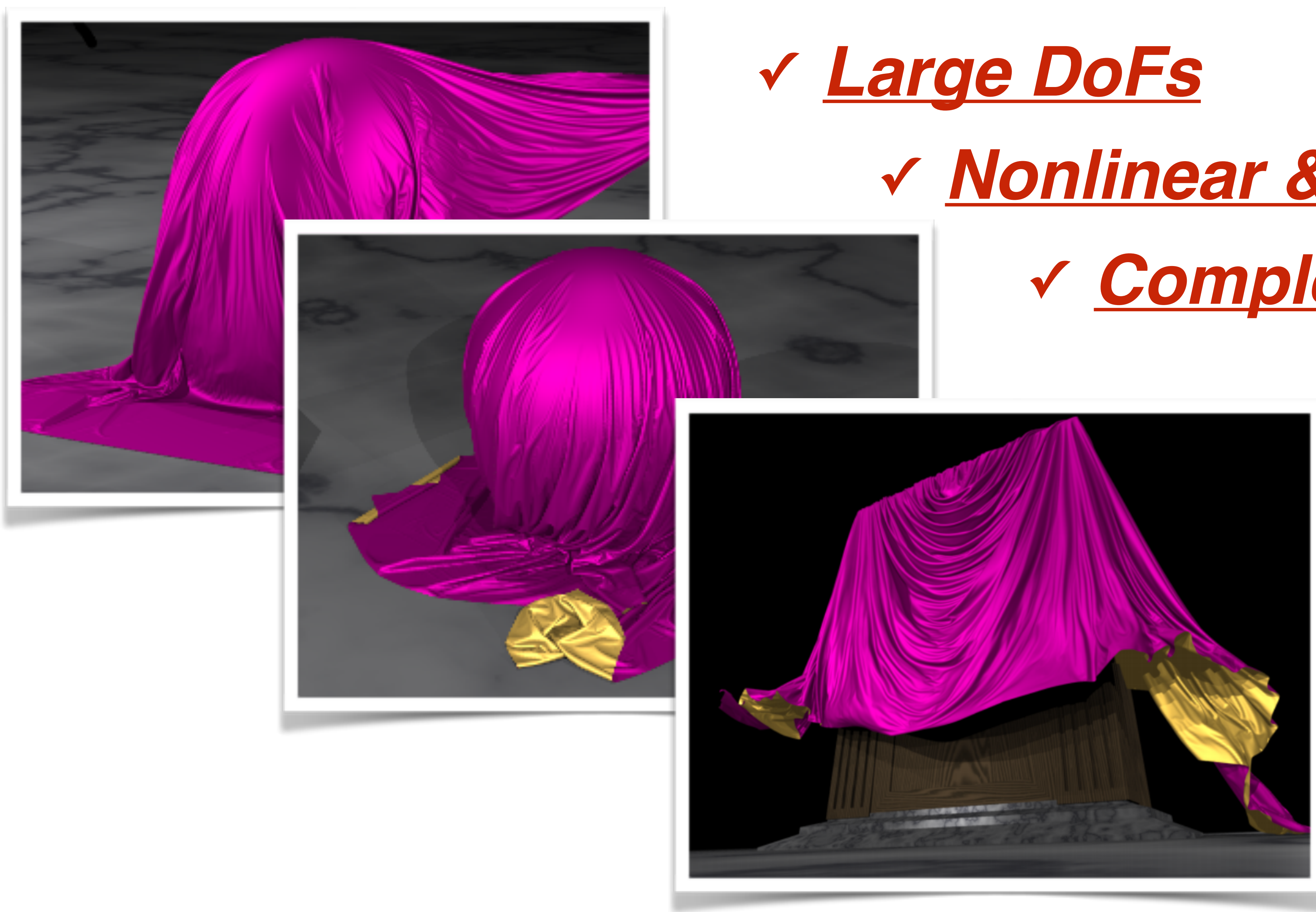


✓ ***Large DoFs***

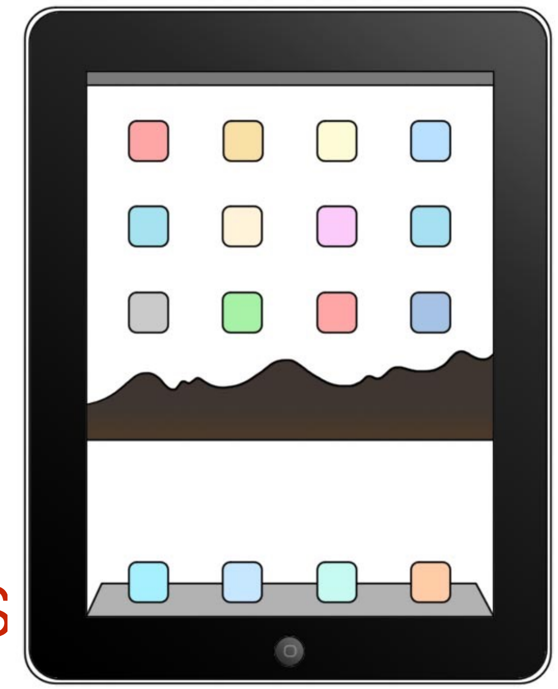
✓ ***Nonlinear & stiff system***

✓ ***Complex collisions***

[Selle et al.09]

Motivation

- Trends: mobile devices gets largely populated
  - Small and flexible
  - Limited computational resources



- Advanced simulation algorithm
  - Multigrid, multilevel, projective dynamics…
  - Still costly for mobile terminals

Motivation

- Possible solution: BS architecture

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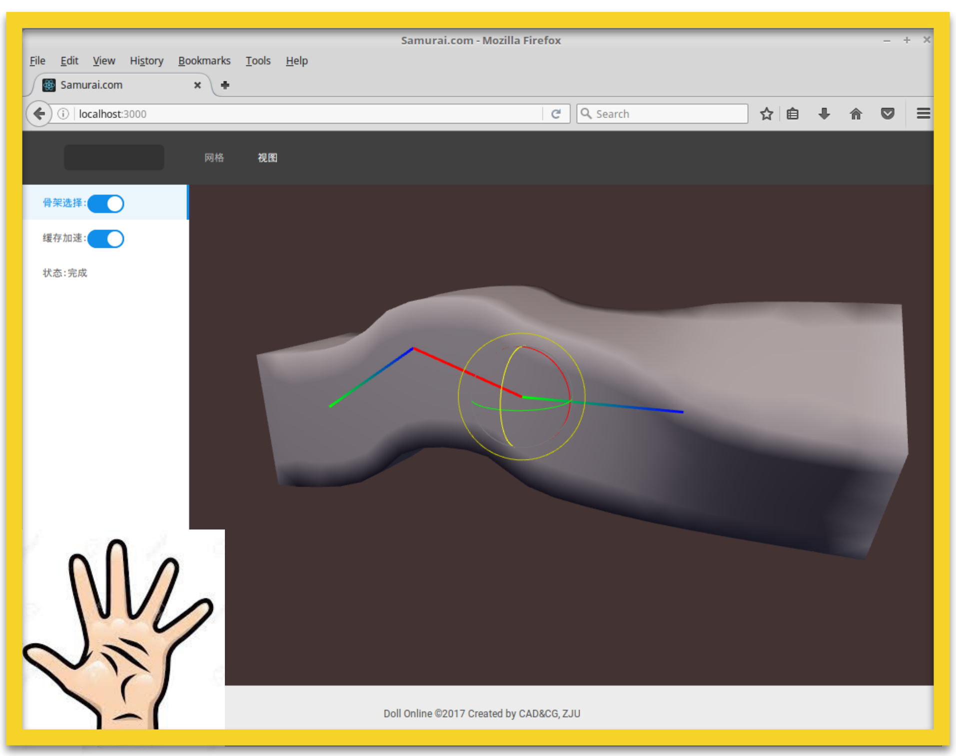

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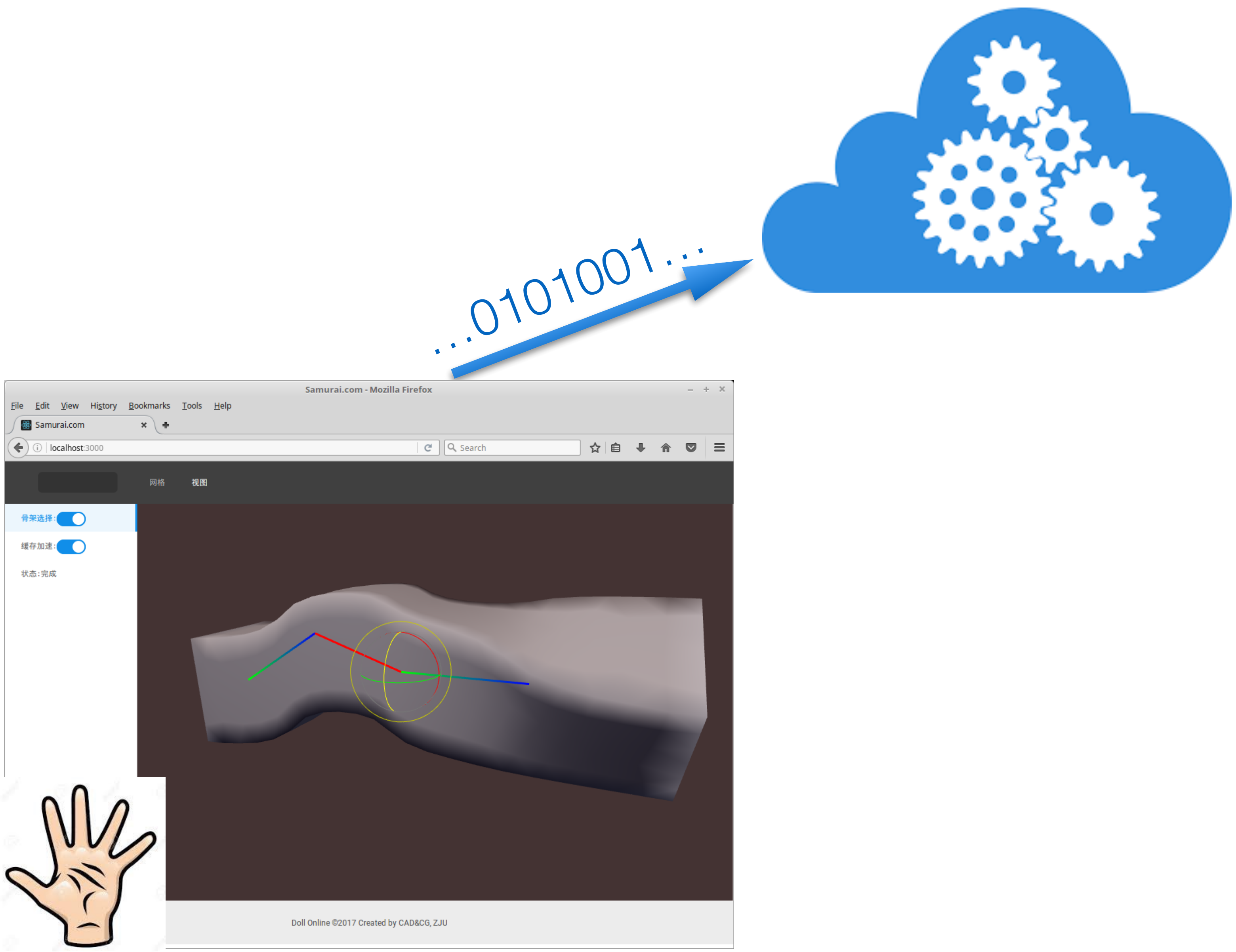

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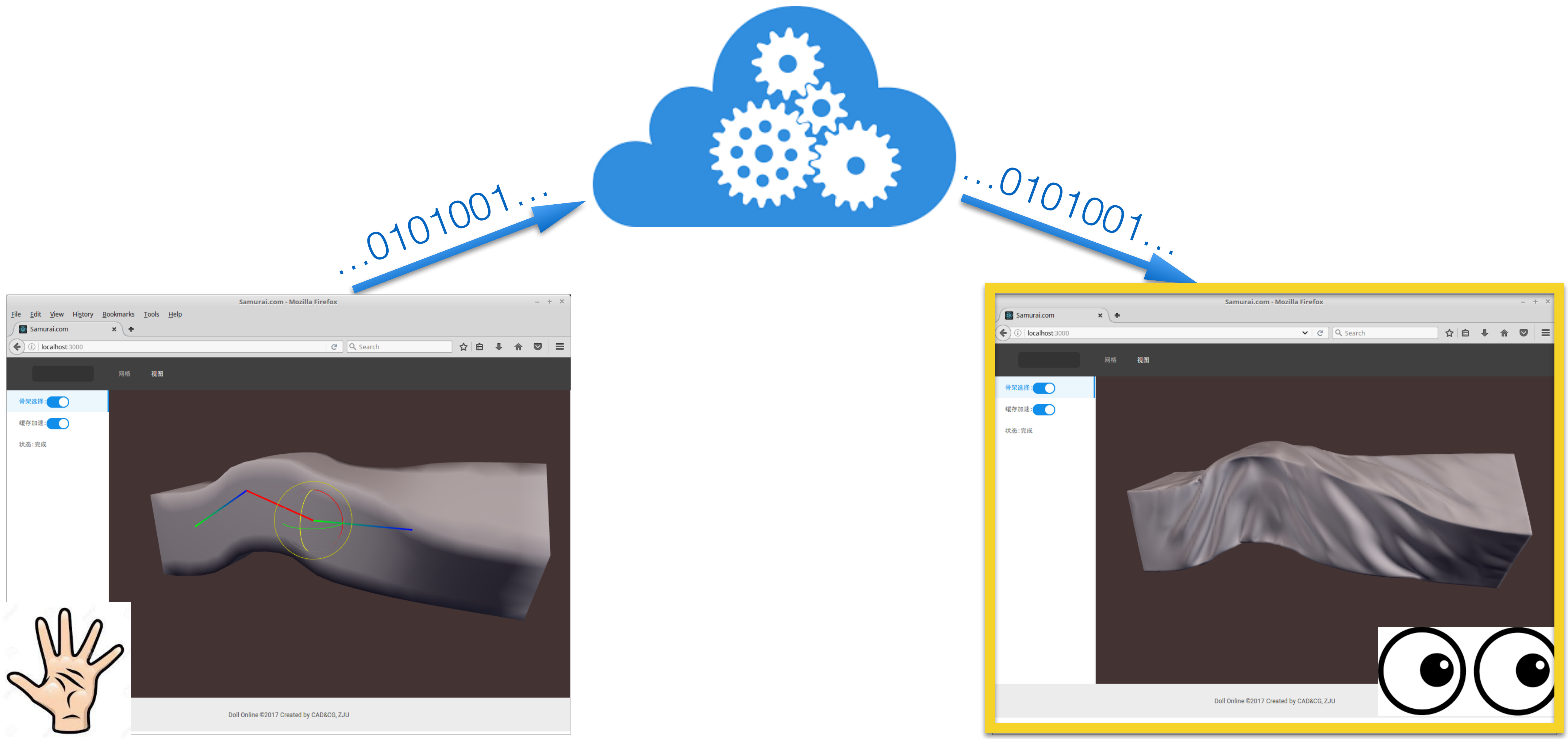

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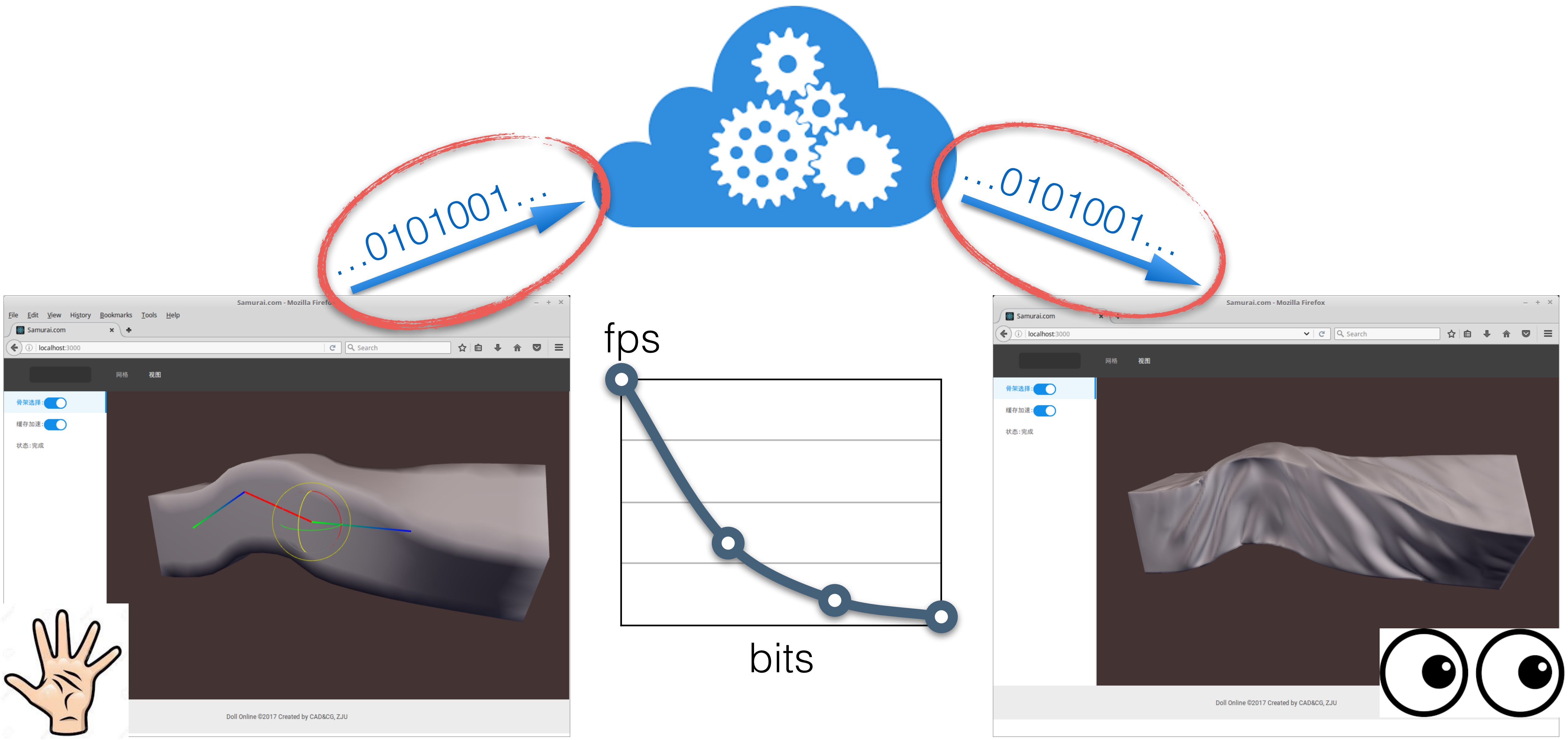

Rationale

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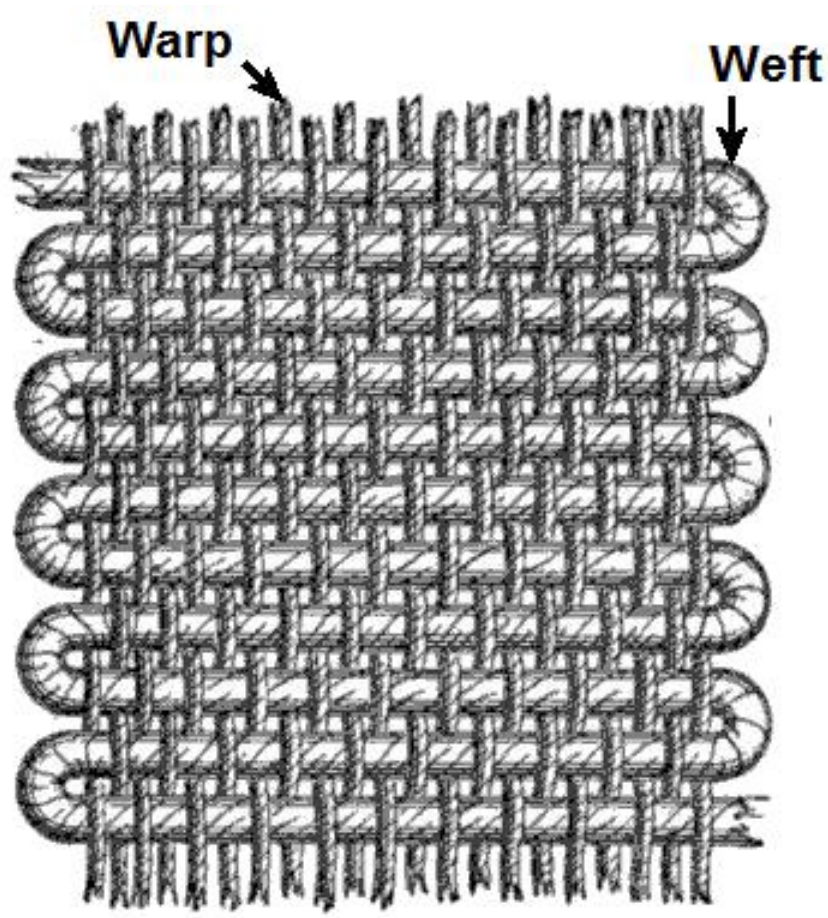
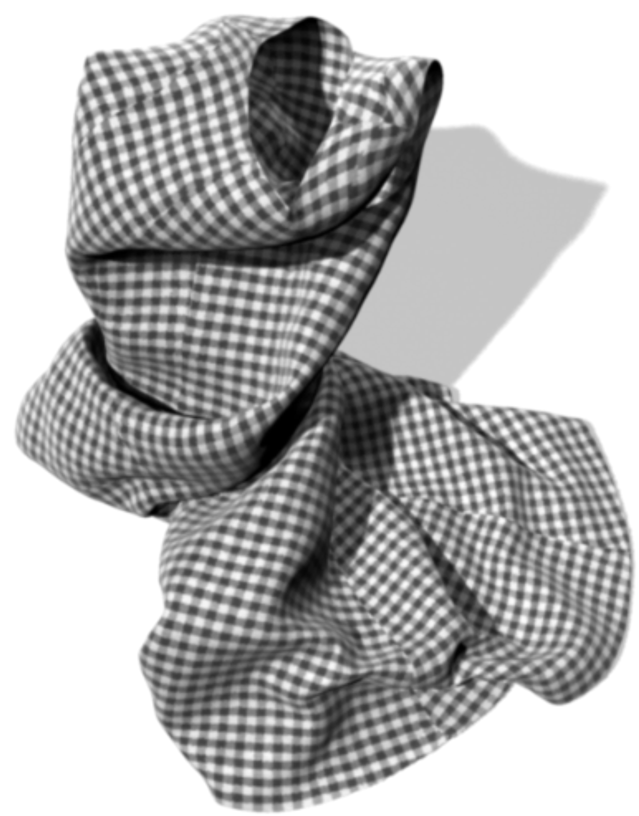
- Cloth generally does not noticeably stretch



Rationale

- Cloth generally does not noticeably stretch
- Numerically: strain limting
- Degrading simulation efficiency

[Goldenthal et al. 07]



[Thomaszewski et al. 09]

[Wang et al. 10]

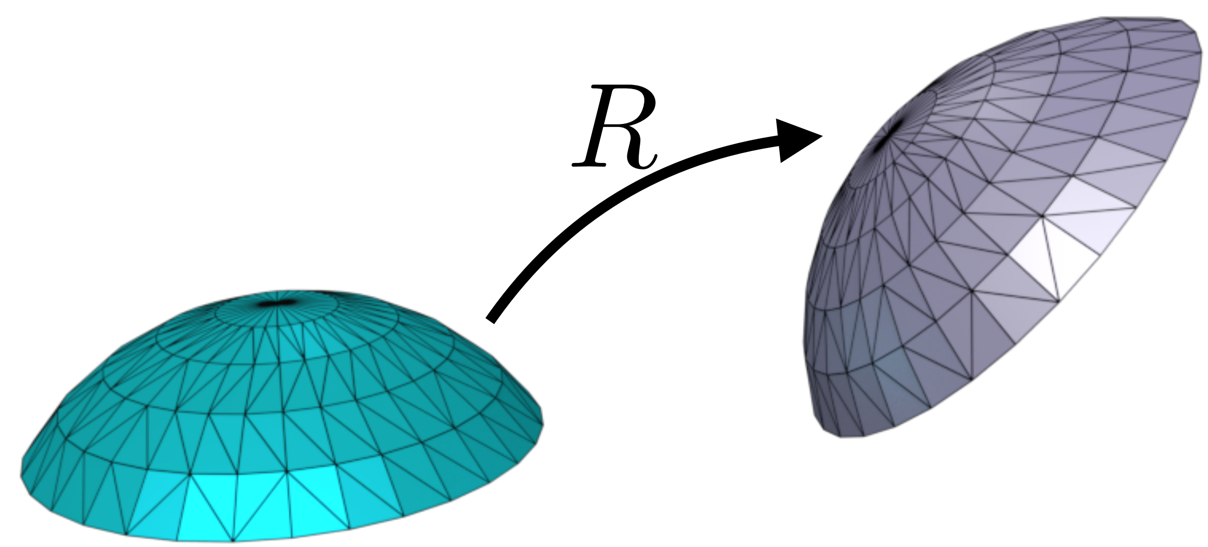
Rationale

- Numerics becomes more evolved, but geometry are intrinsically *“simpler”*
- More compact representation?

Previous Work

Previous Work

- Predictive method
  - Local rigid transformation



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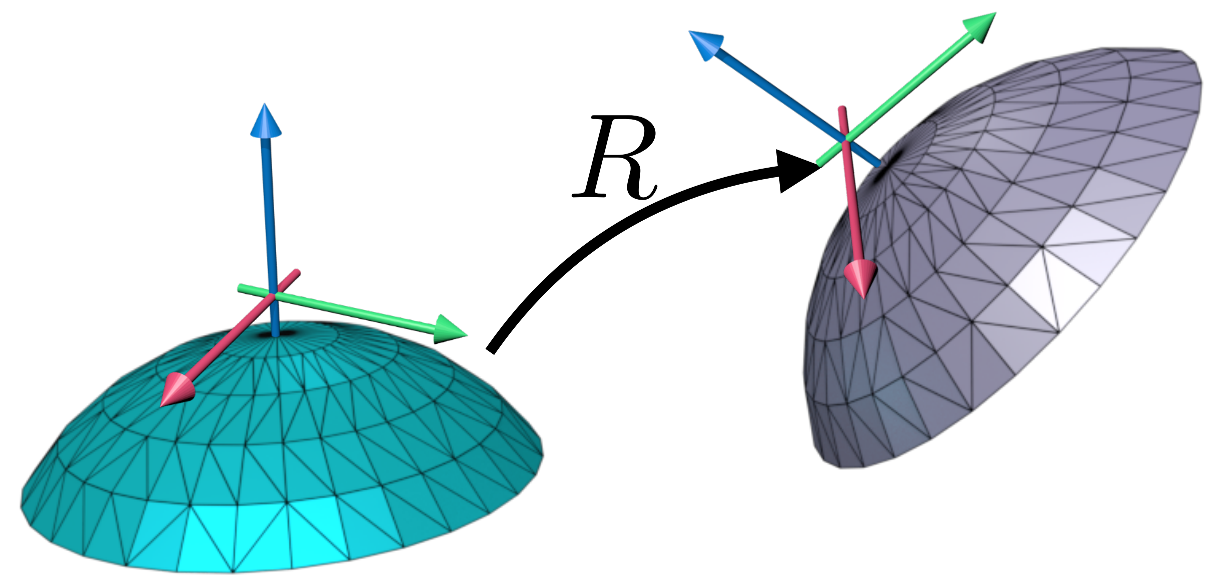

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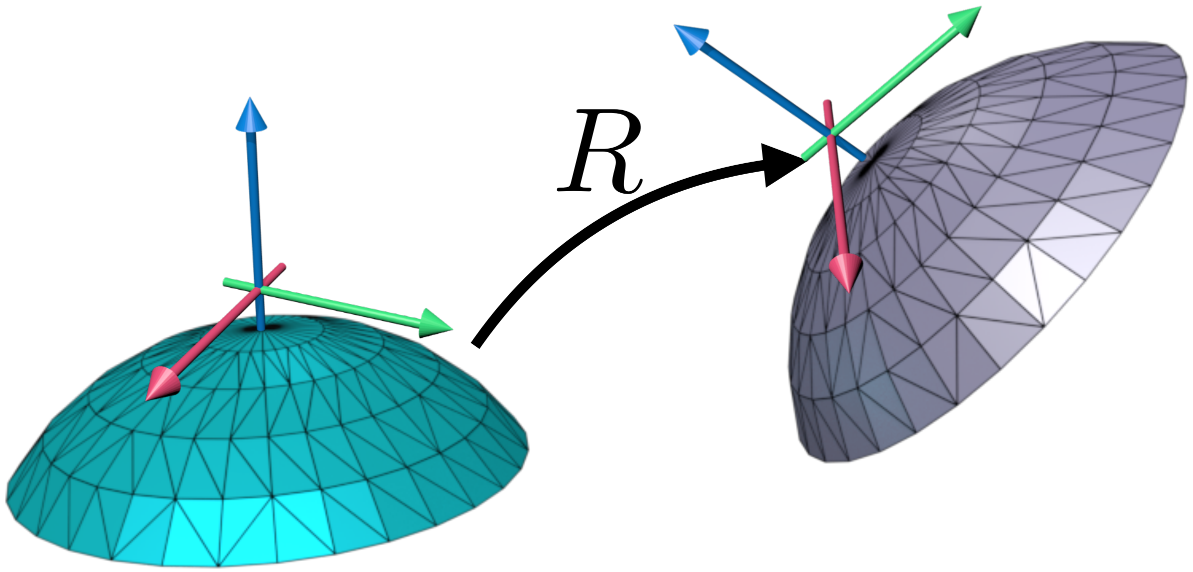
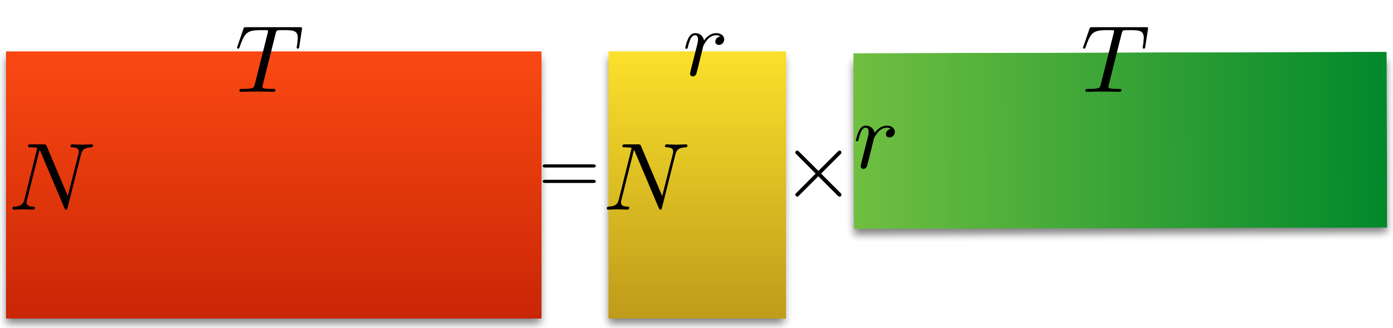


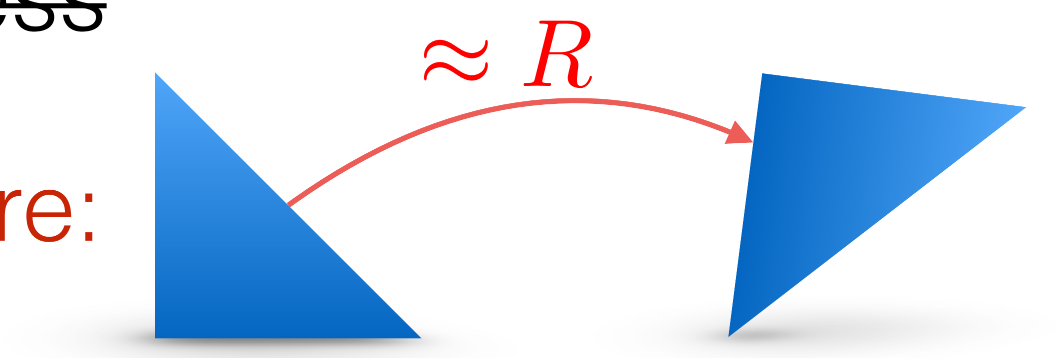
- Spectral methods
  - Geometrically smooth



Basic Idea

- Assumption: ~~Local rigidity and geometric smoothness~~

Require:



- Decompose the deformation into two separate parts
  - In-plane: small stretch or shear
  - Out-plane: large bending or torsion

Basic Idea

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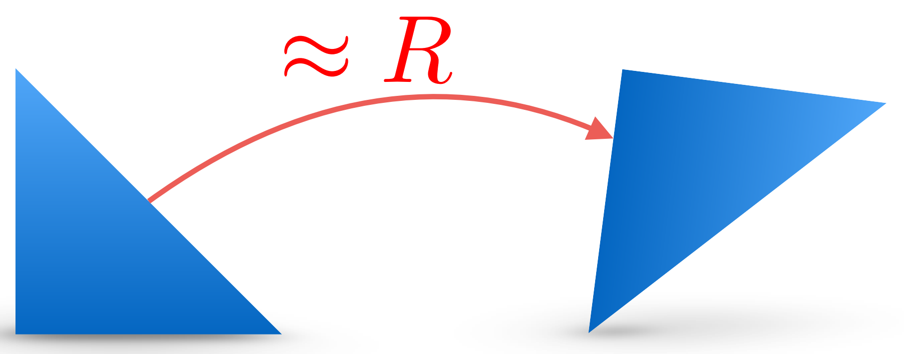
Require:



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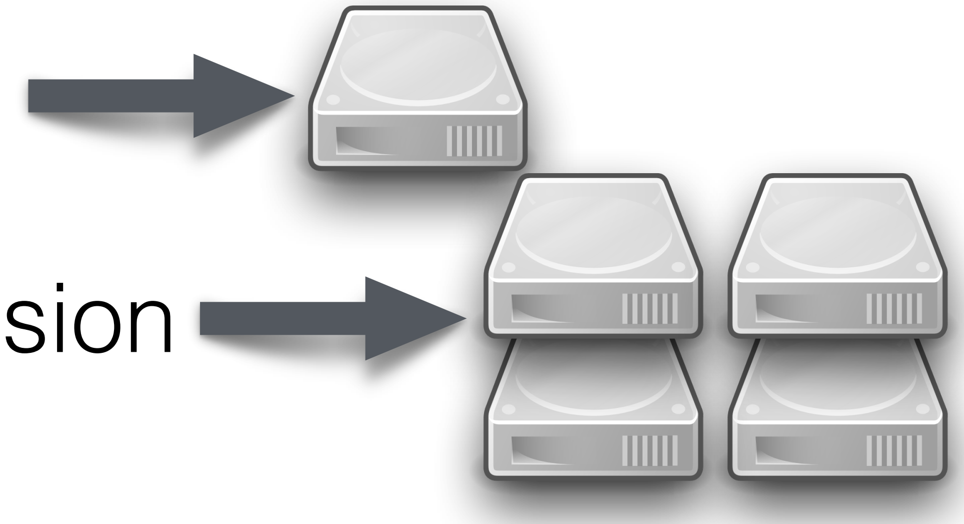
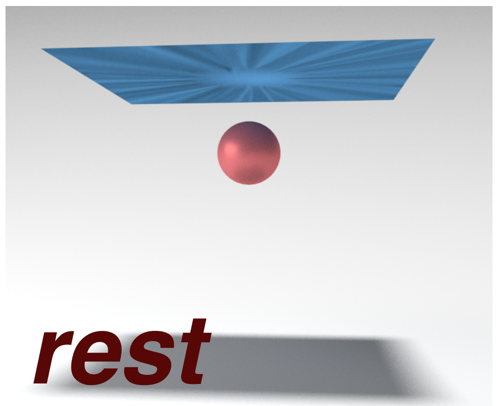
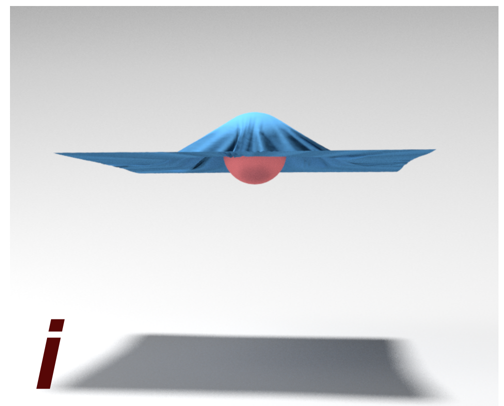


Overview





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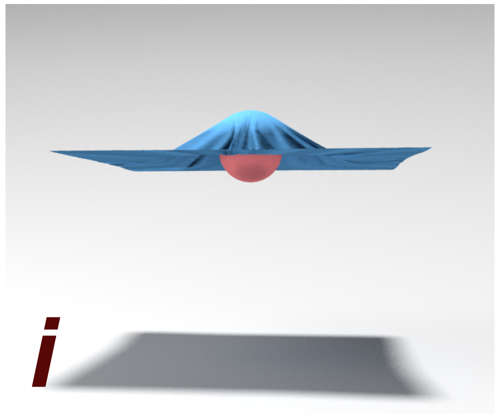

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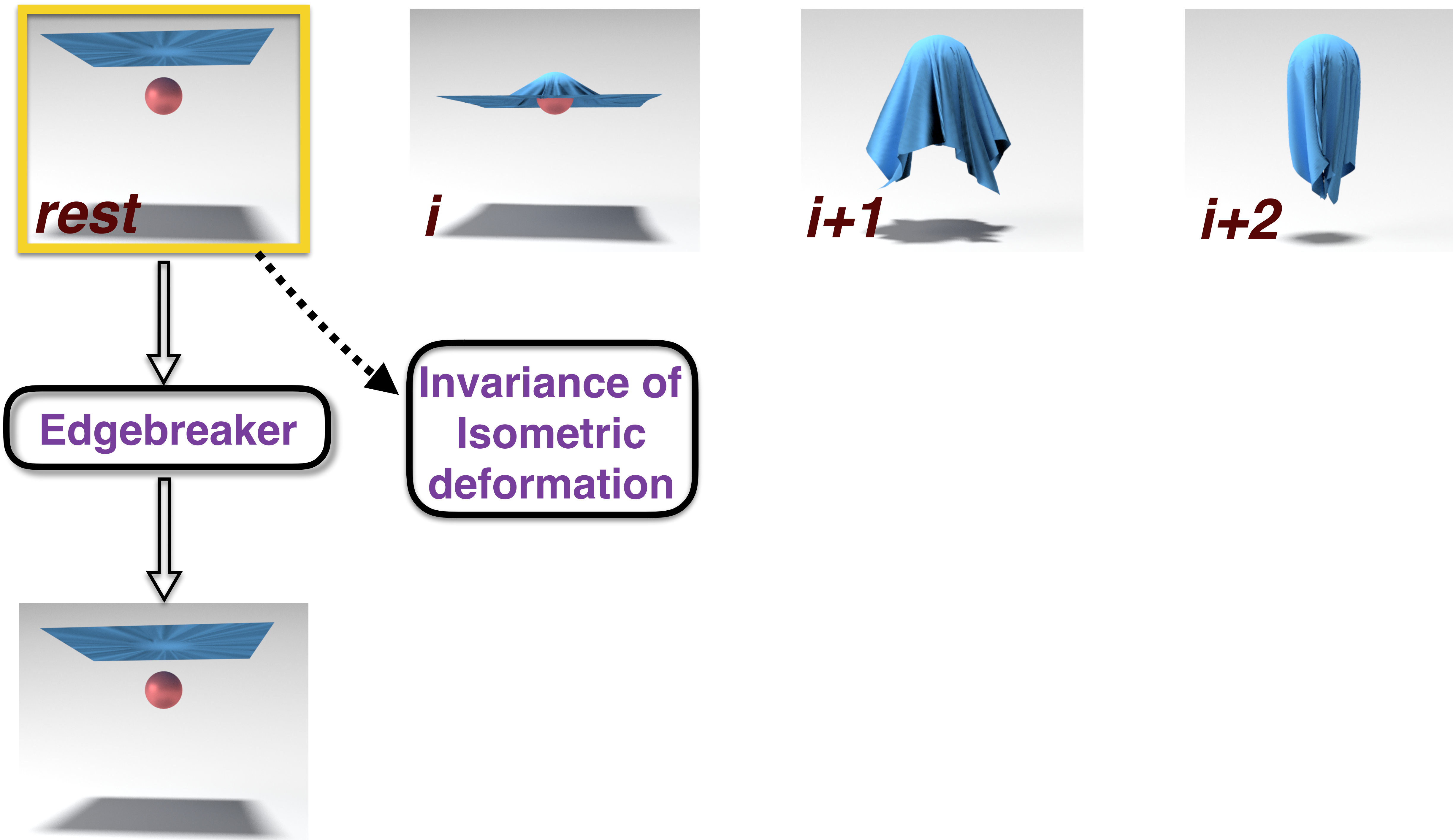
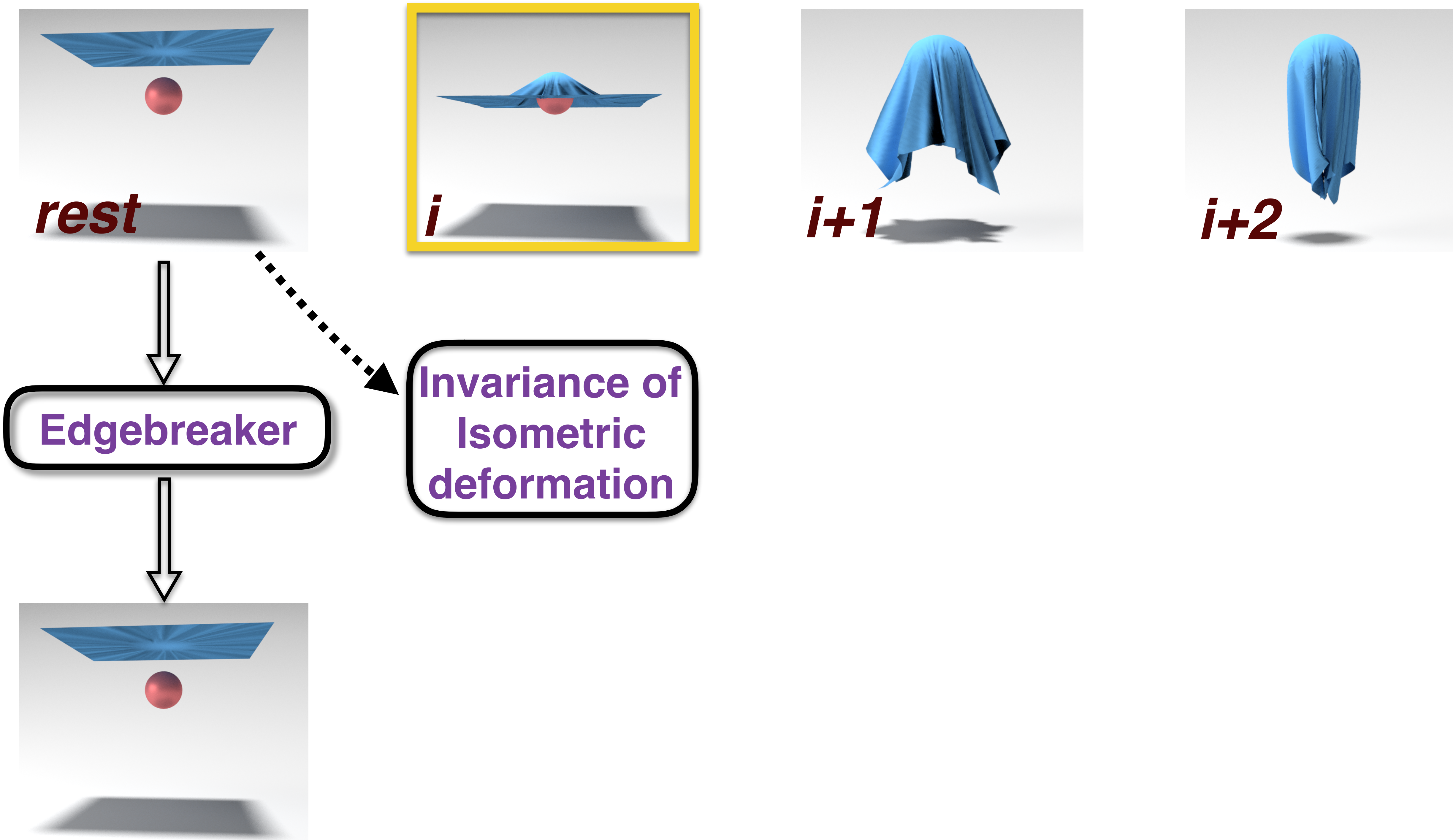

rest
i
i+1
i+2
Edgebreaker
Invariance of Isometric deformation

Overview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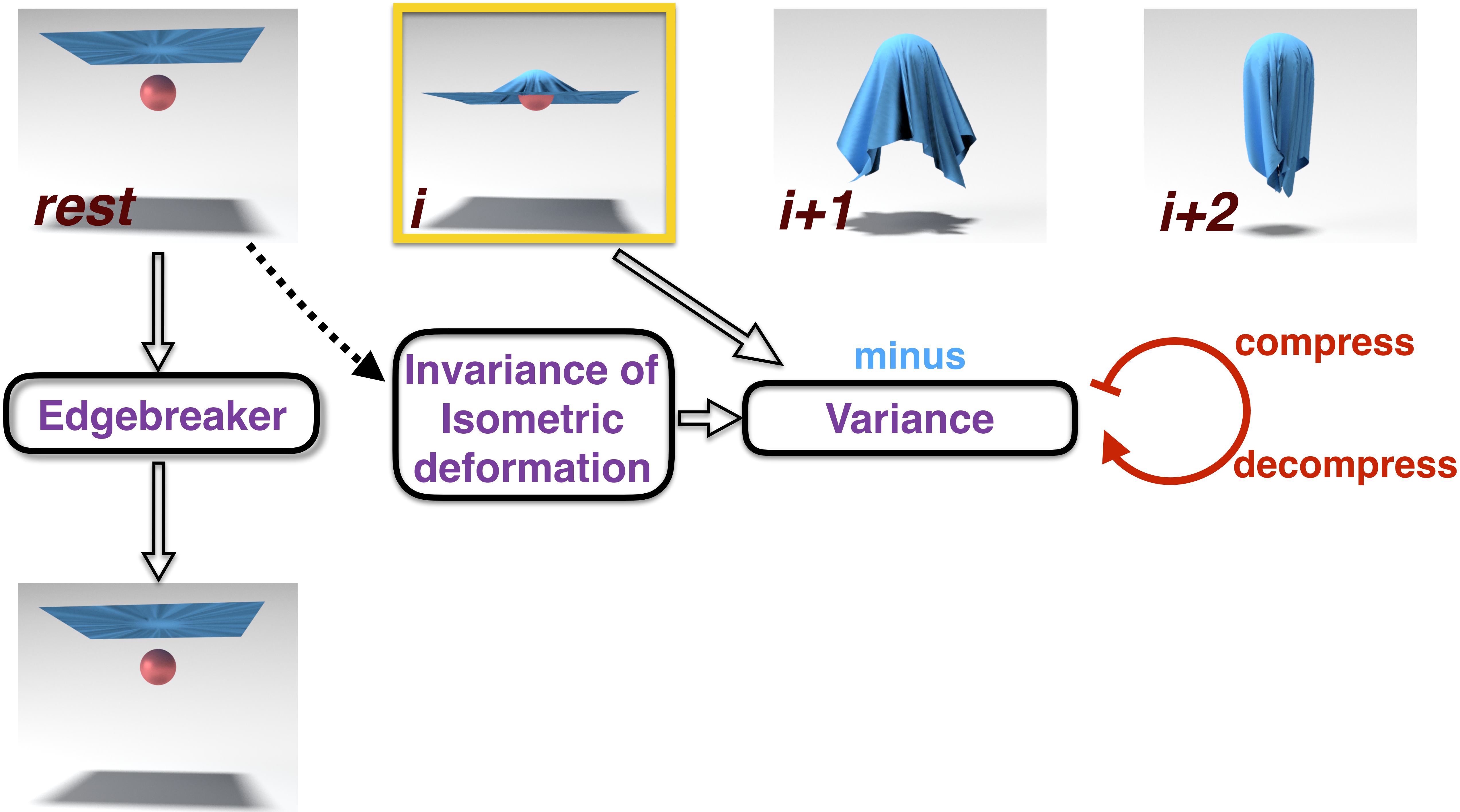
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minus
Variance
compress
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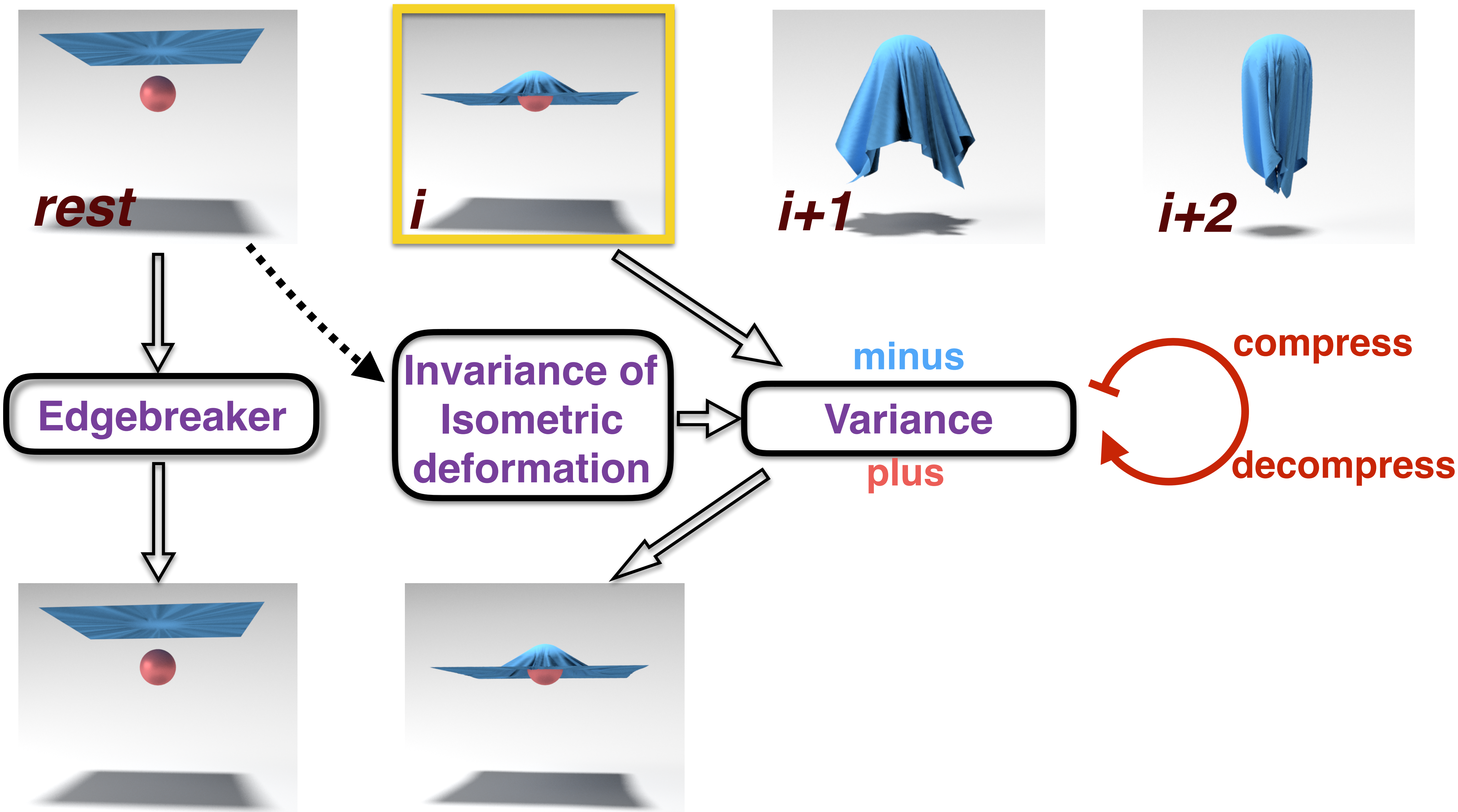
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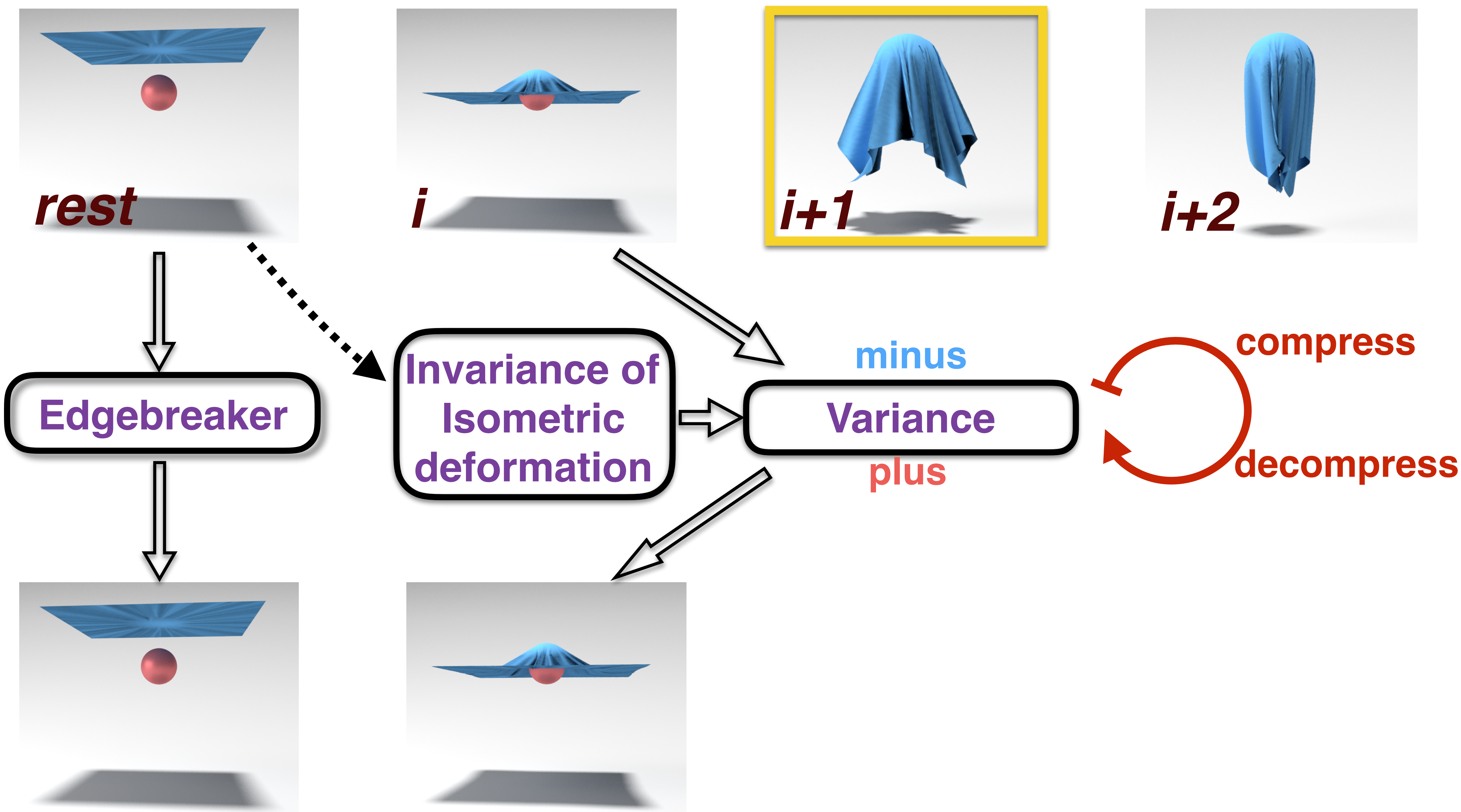
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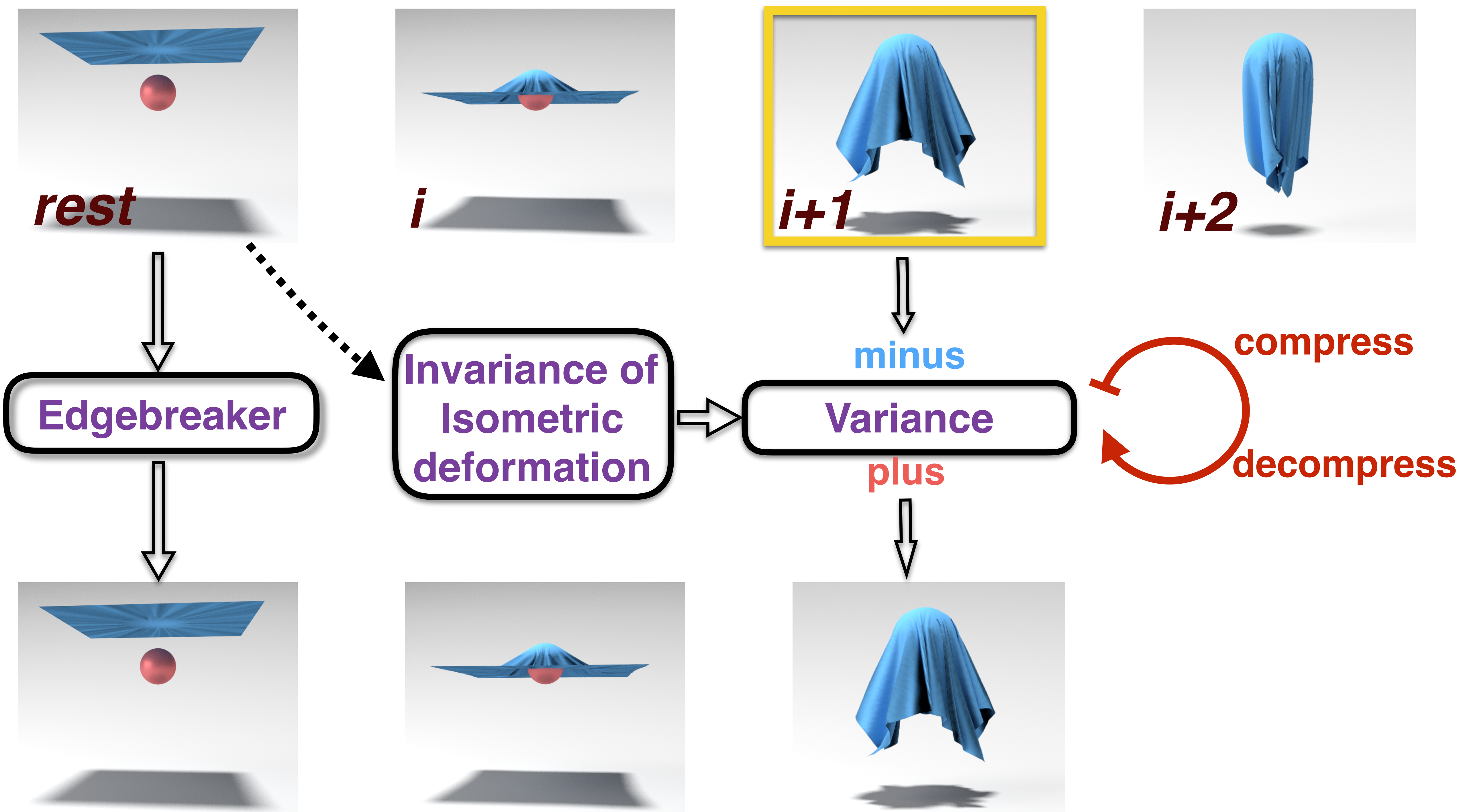
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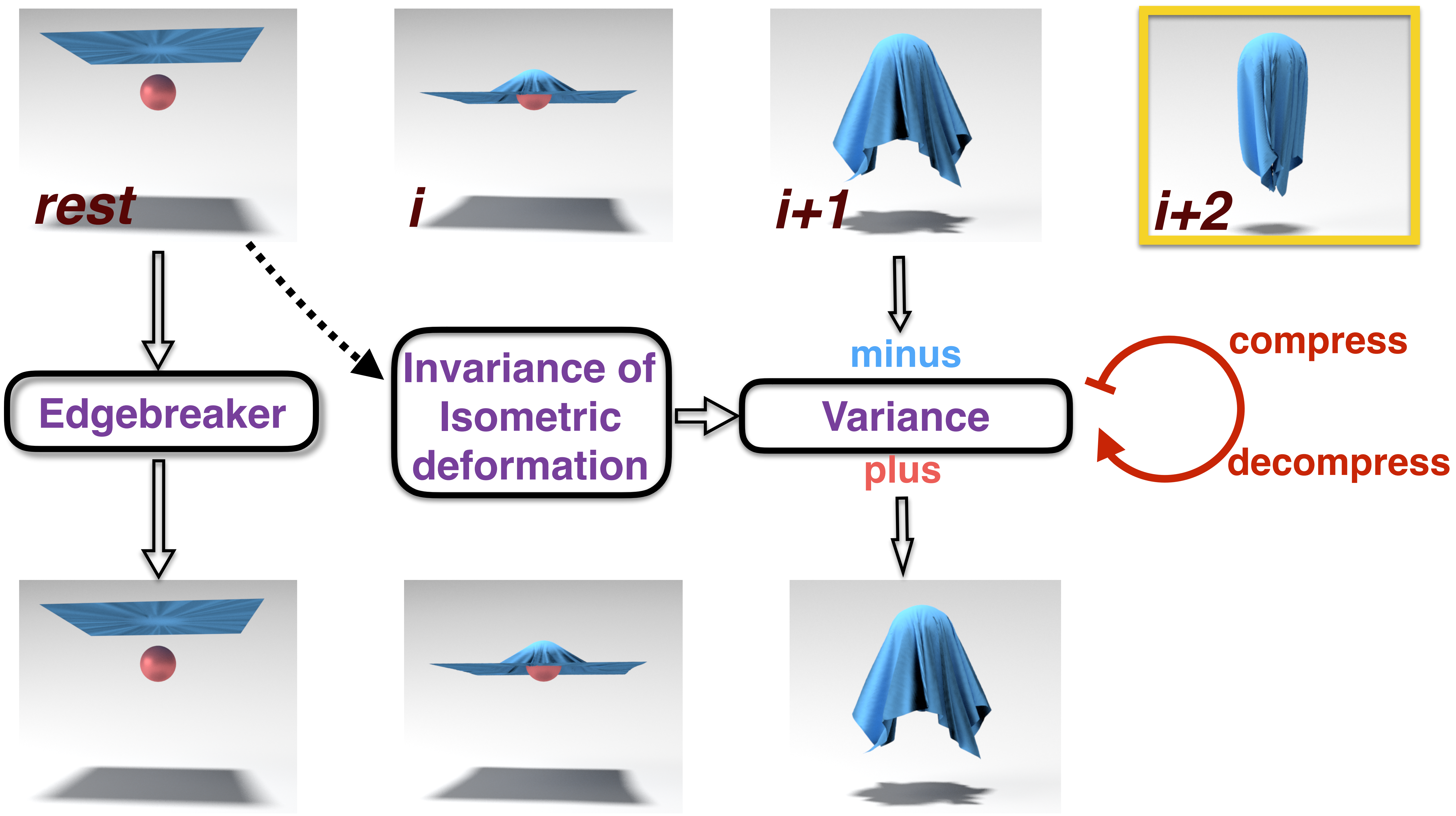
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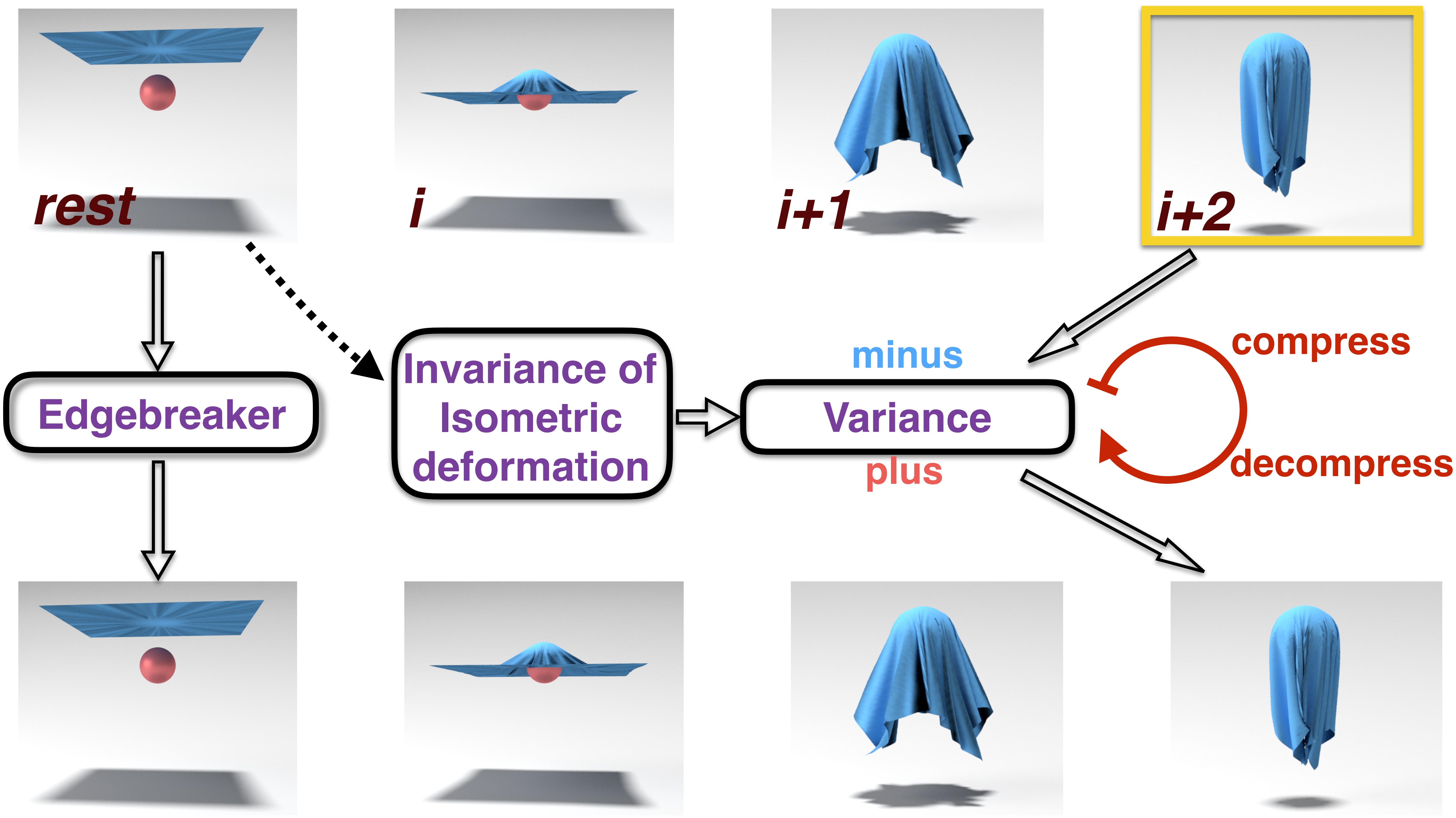

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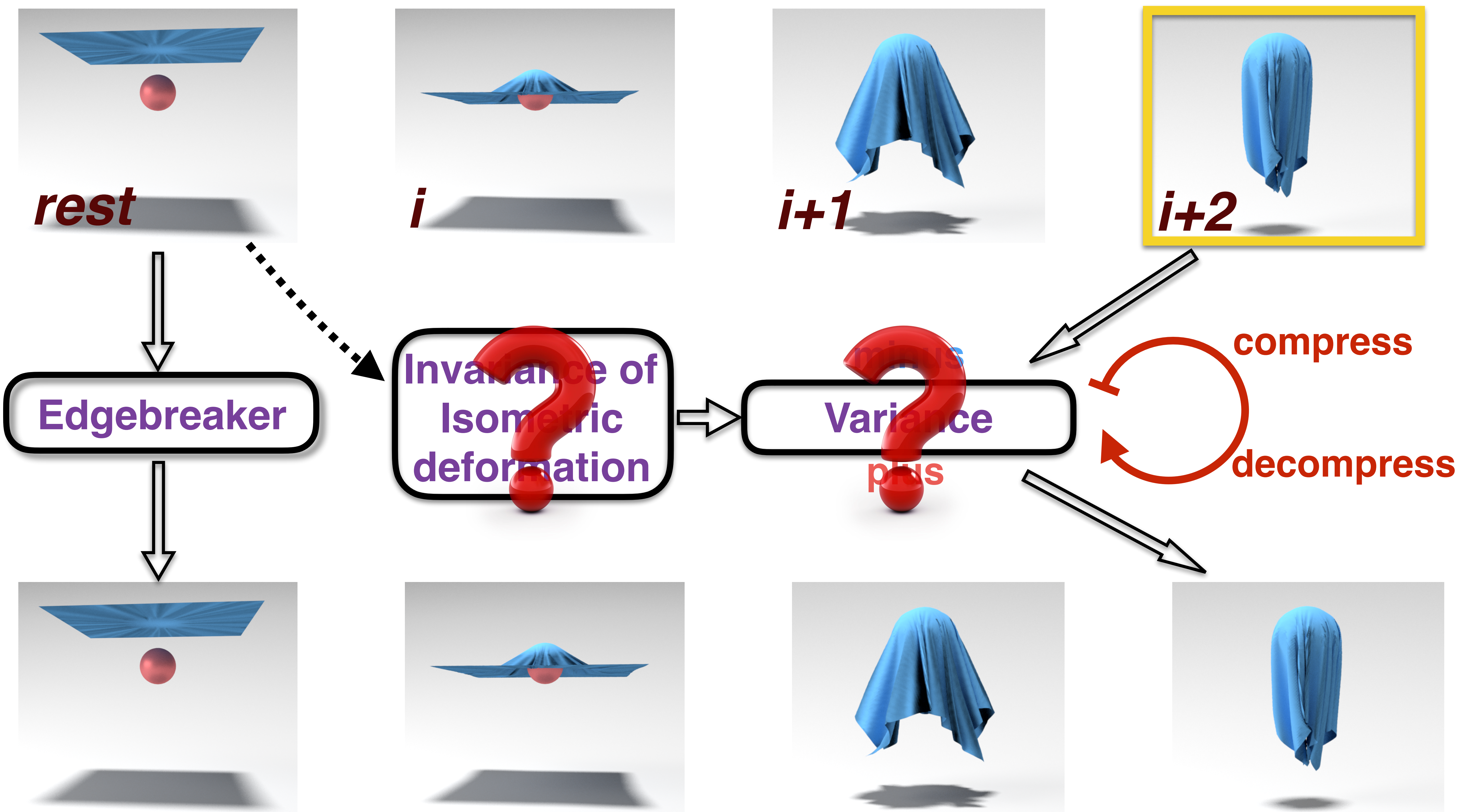
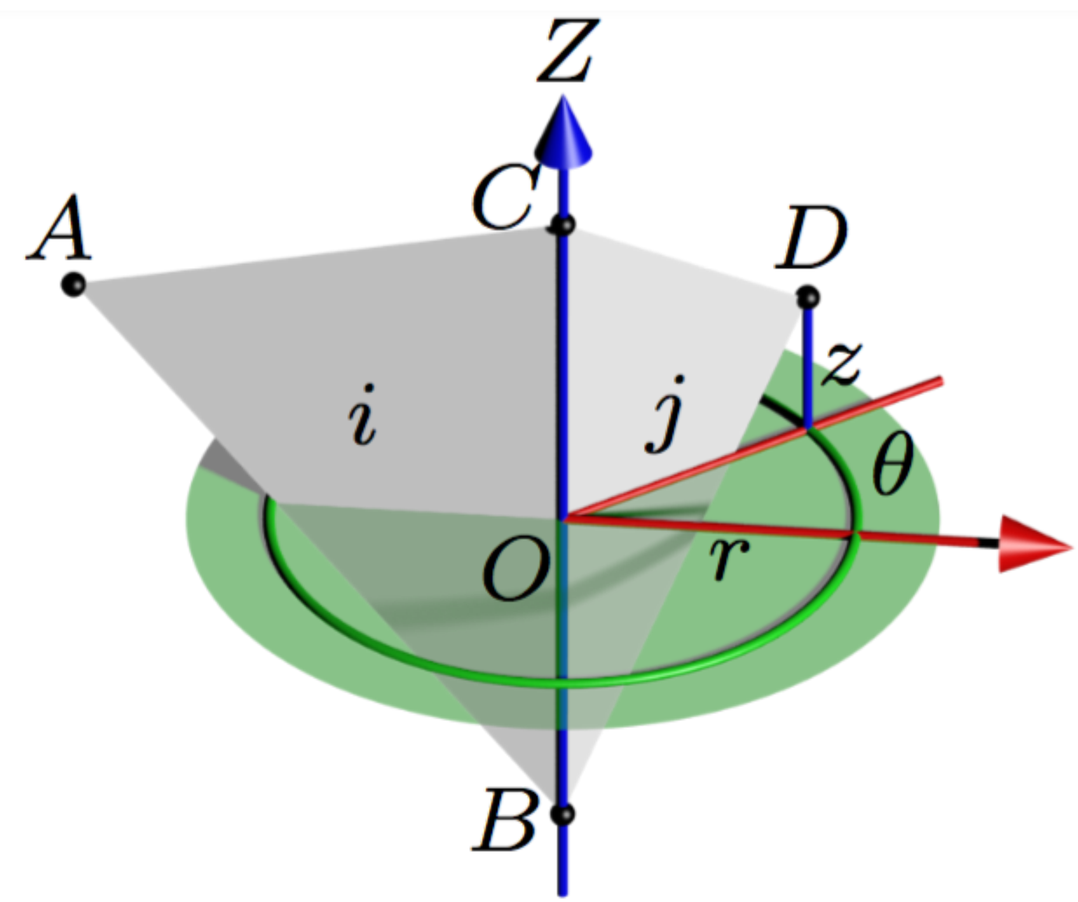


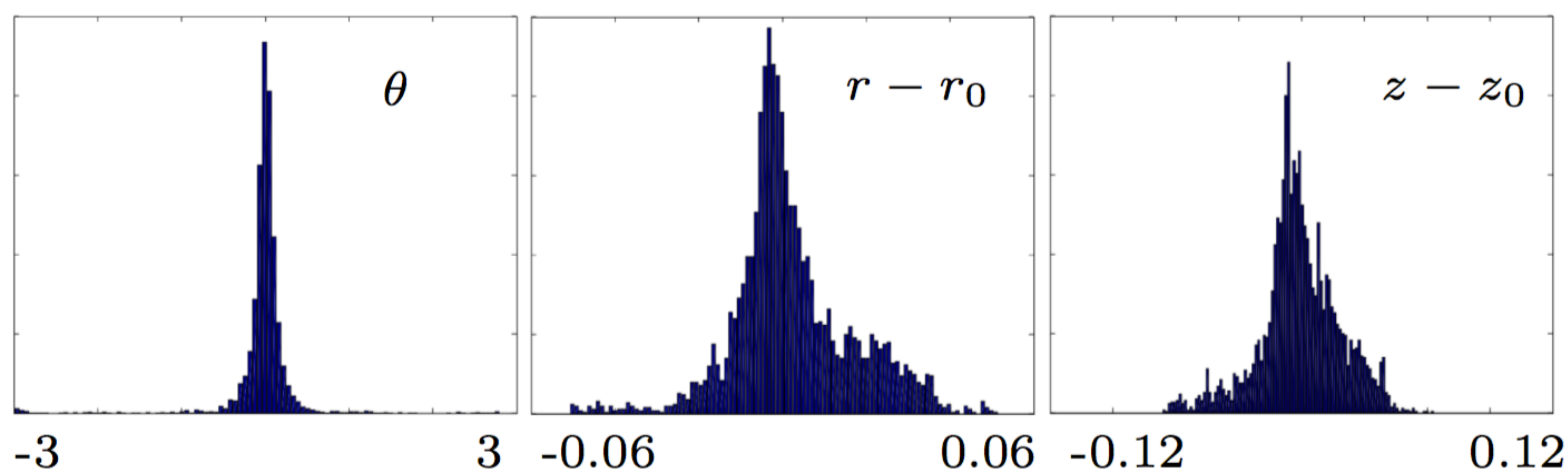
Local Cylindrical Coordinate (LCC)

- For a triangle pair,

$$(x_1^D, x_2^D, x_3^D) \rightleftharpoons (\theta, r, z),$$
$$\text{wrt.} \quad \Delta ABC$$

- Normalization: Δ / L
- Cloth with strain limiting (upper bound for stretch ratio 5%)

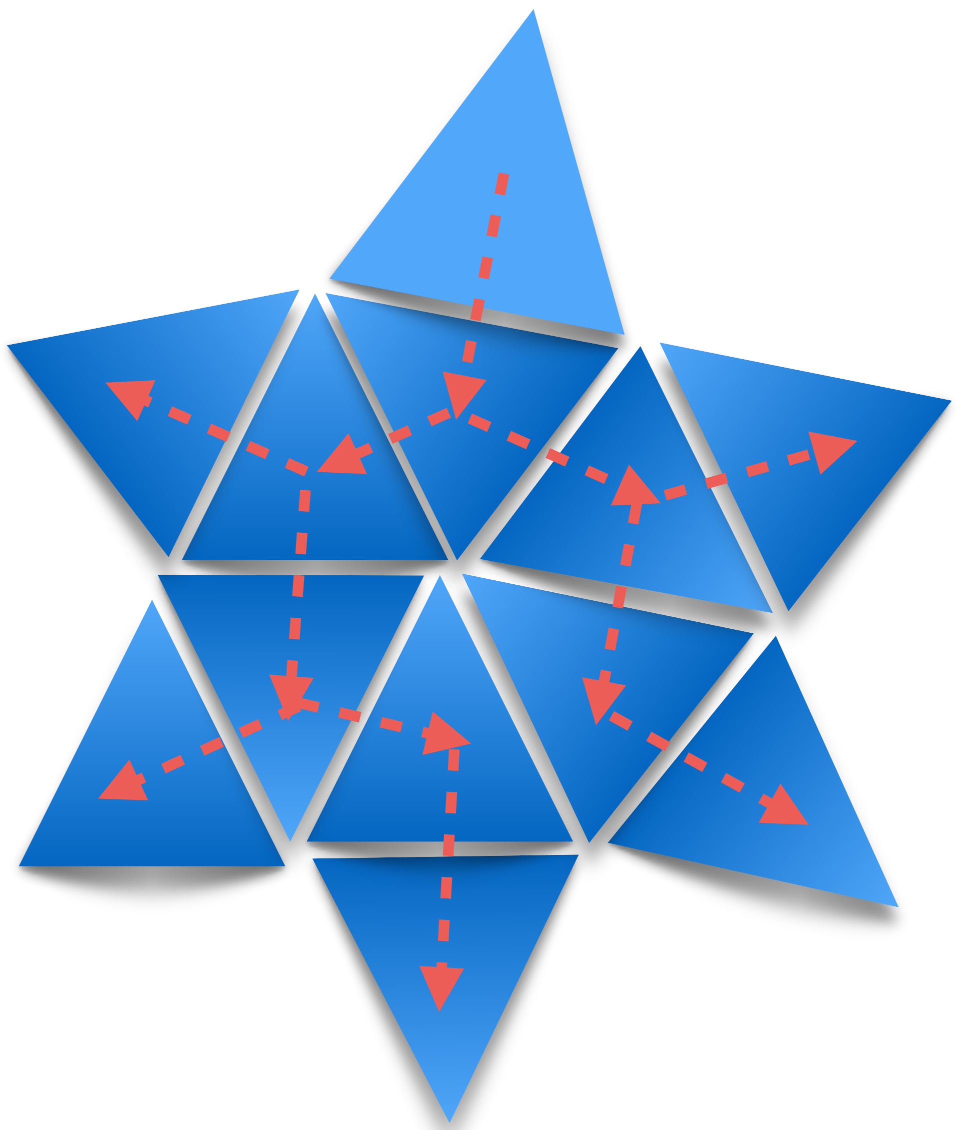




Encoding & Decoding

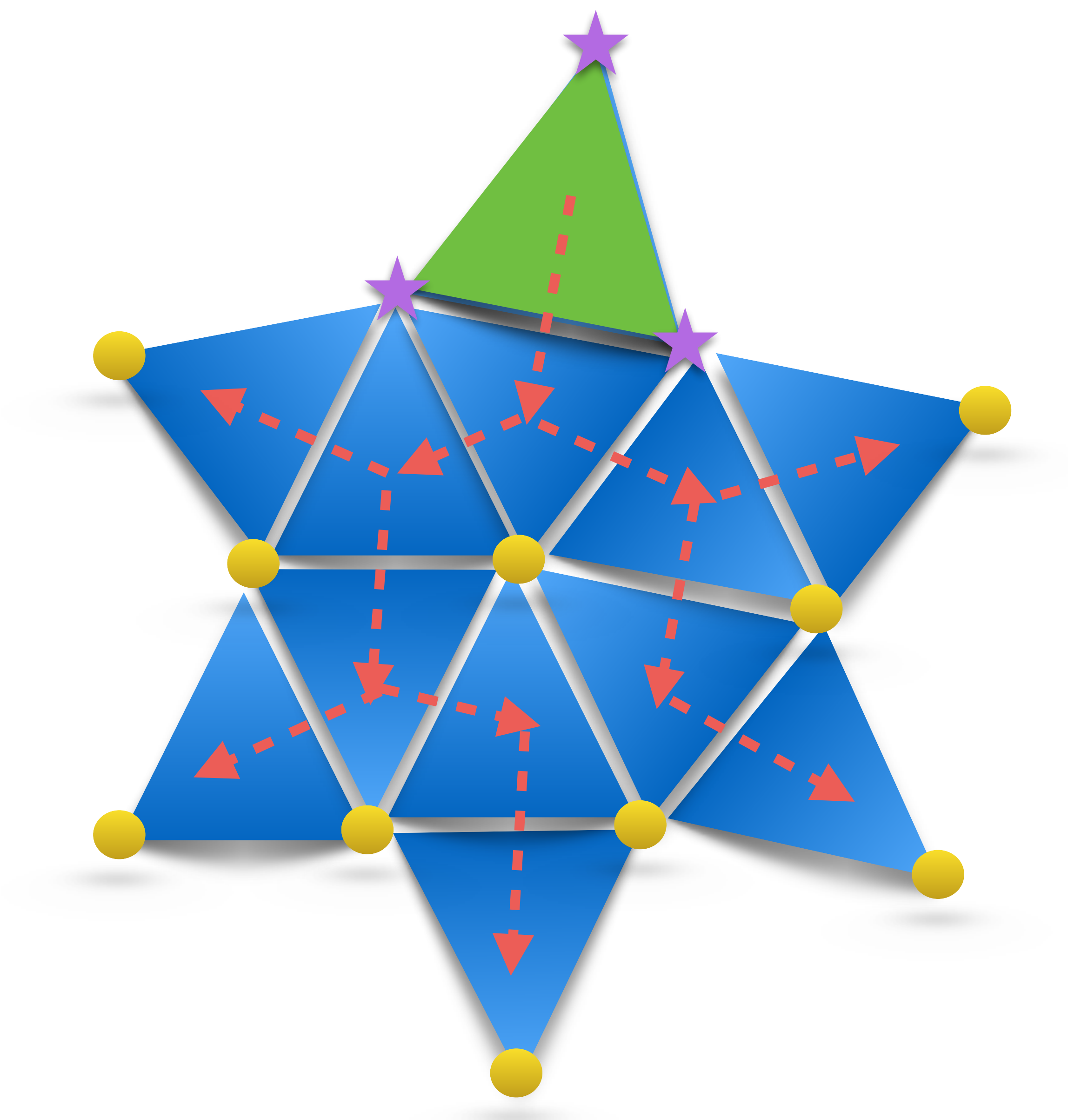
Encoding & Decoding

- Construct spanning tree



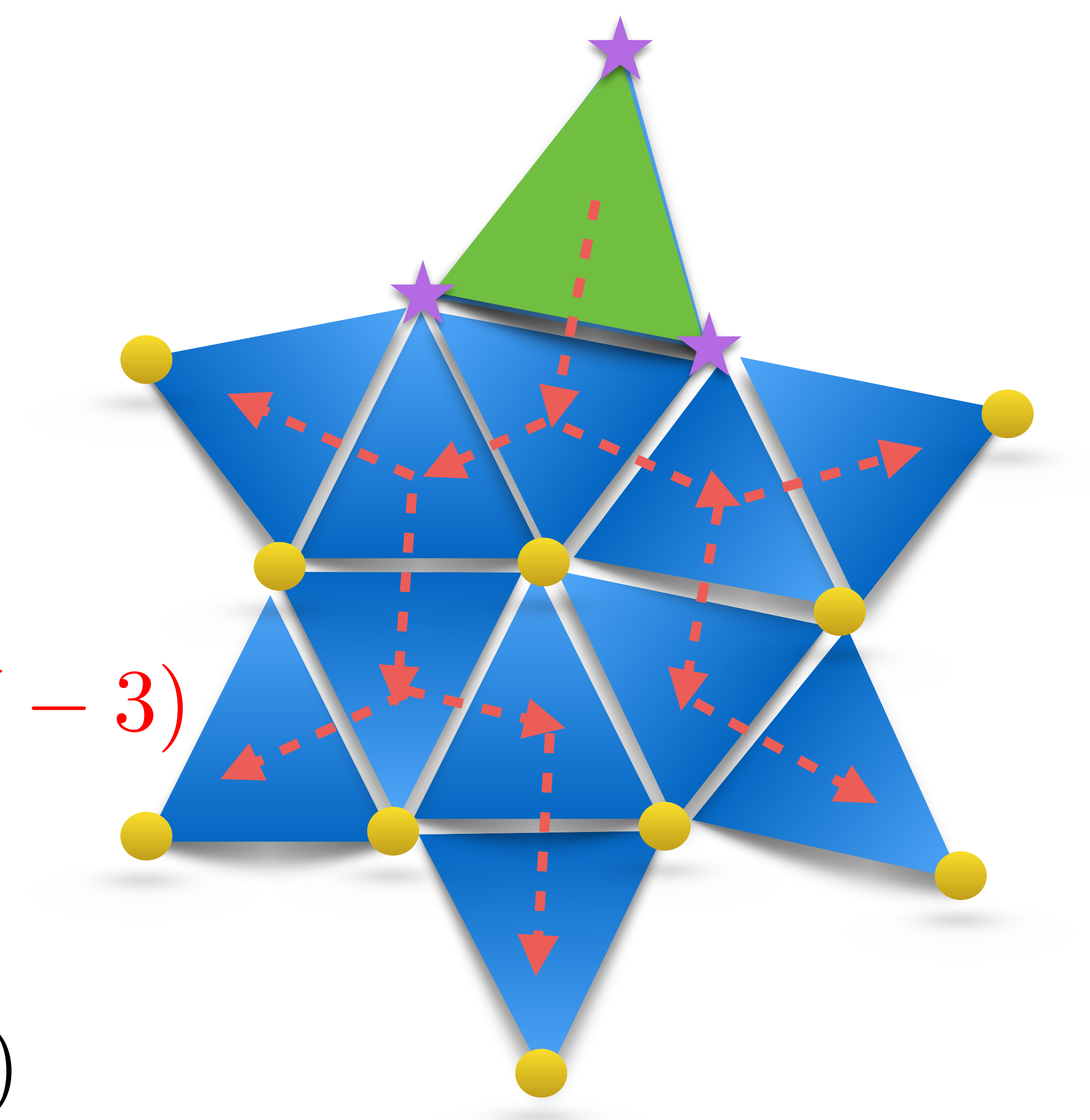
Encoding & Decoding

- Construct spanning tree
- Select root and traverse the tree



Encoding & Decoding

- Construct spanning tree
- Select root and traverse the tree
- Encoding
  - Input: $x(t)\ \ lcc(0)$
  - Output: $root(t)(3)\Delta lcc(t)(N-3)$
- Decoding
  - Input: $lcc(0)\Delta lcc(t)\ \ root(t)$
  - Output: $\hat{x}(t)$



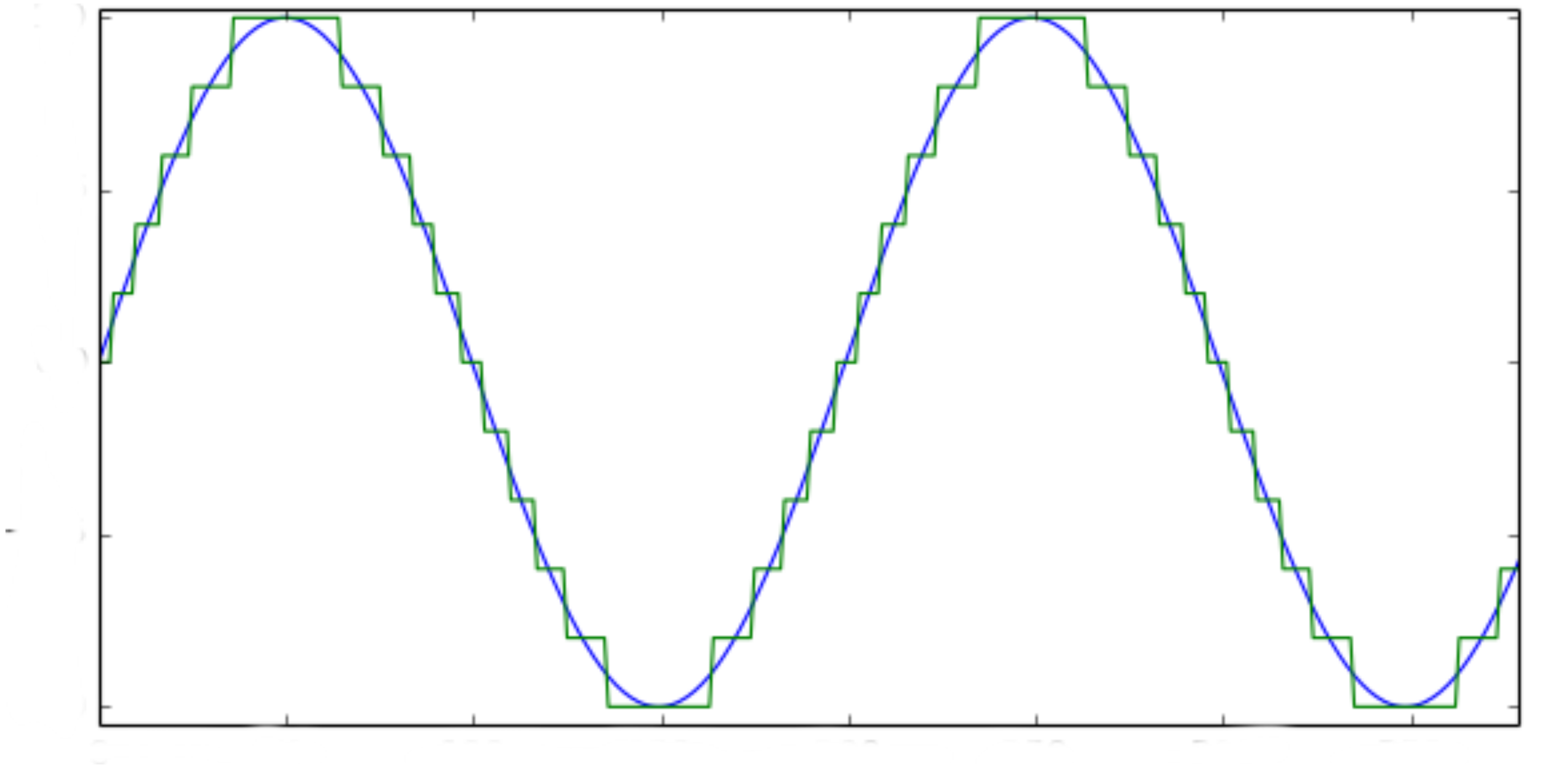
Encoding & Decoding

- Spanning tree construction
  - No strong restriction
  - For irregular mesh, geometric info may be very helpful
- Traversal order, BFS or DFS?
  - Difference on compression ratio (< 5%)

Quantization

- Mapping large set of values to smaller one
- Uniform quantization for $x \in [-\sigma, \sigma]$

$$q(x) = \text{floor}(2^b x / \sigma)$$

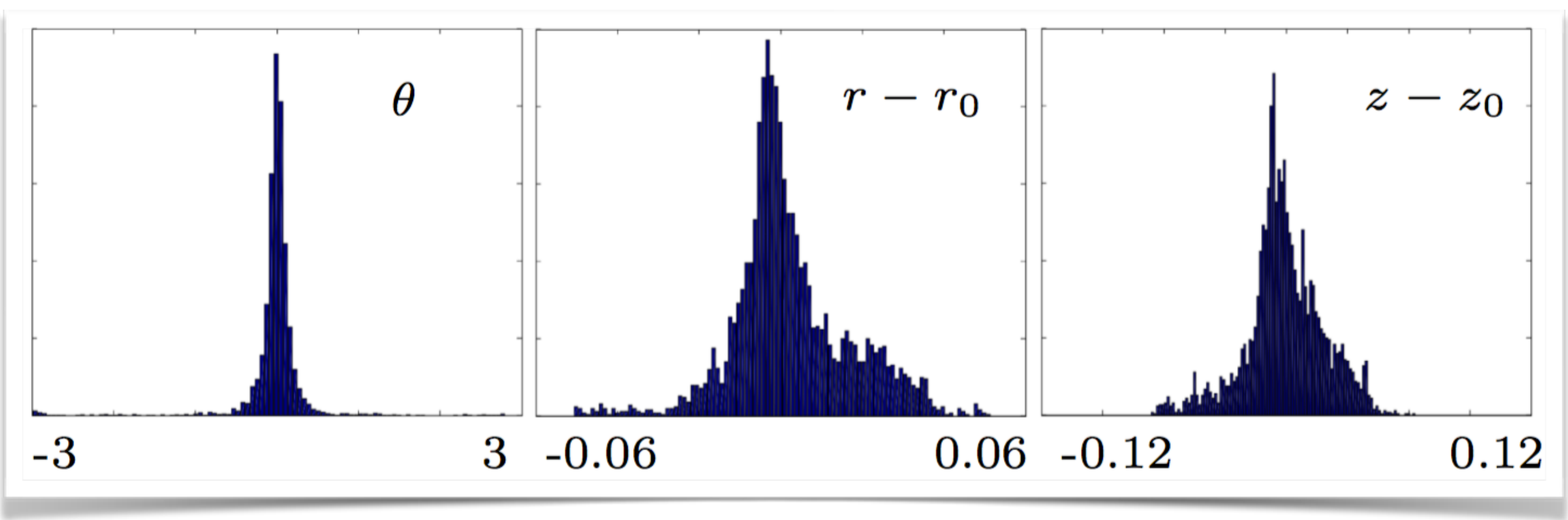


Quantization

Quantization

- Optimal bits difference

$$b_{rh} = b_\theta - \lfloor 0.5 - \log_2(\sigma) \rfloor$$



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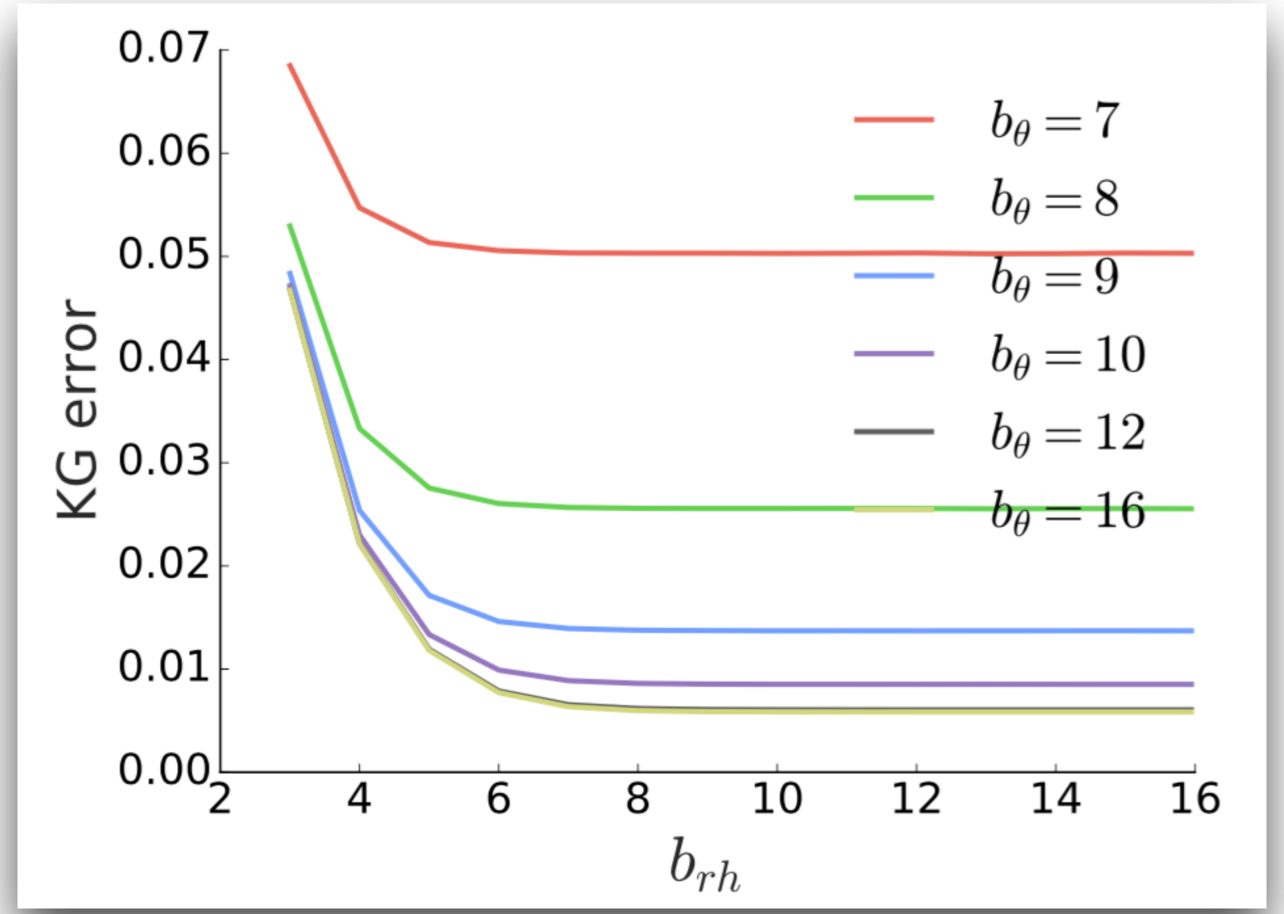

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- Optimal bits difference

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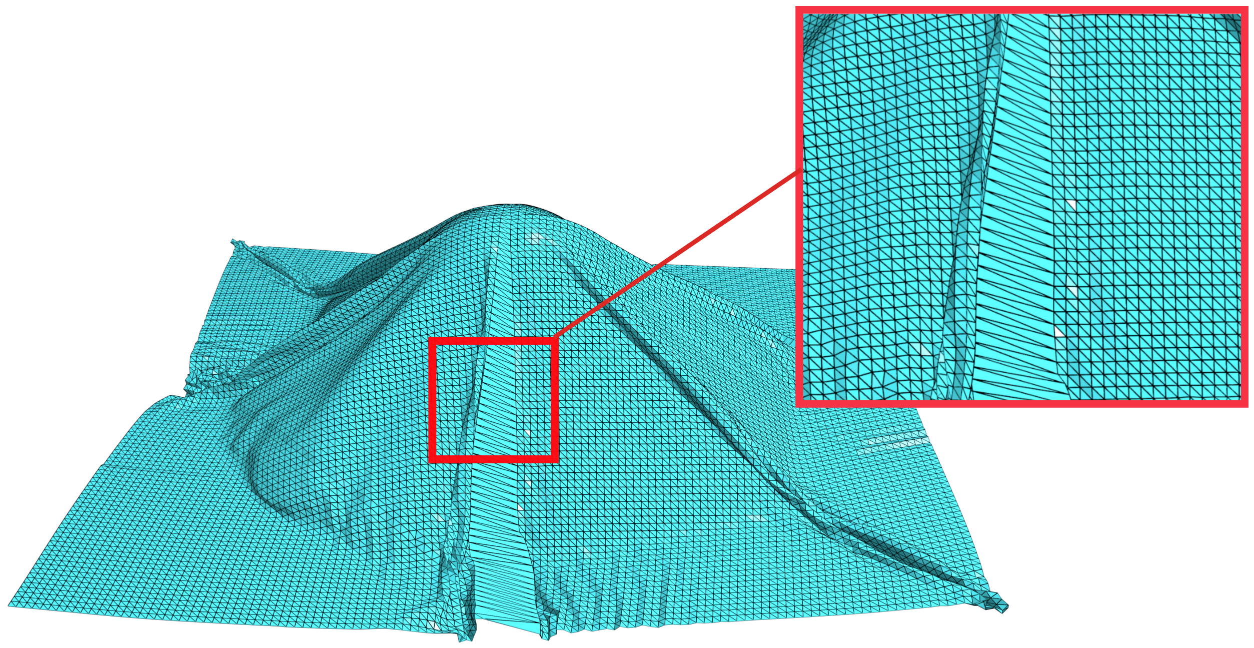
- Naive implementation

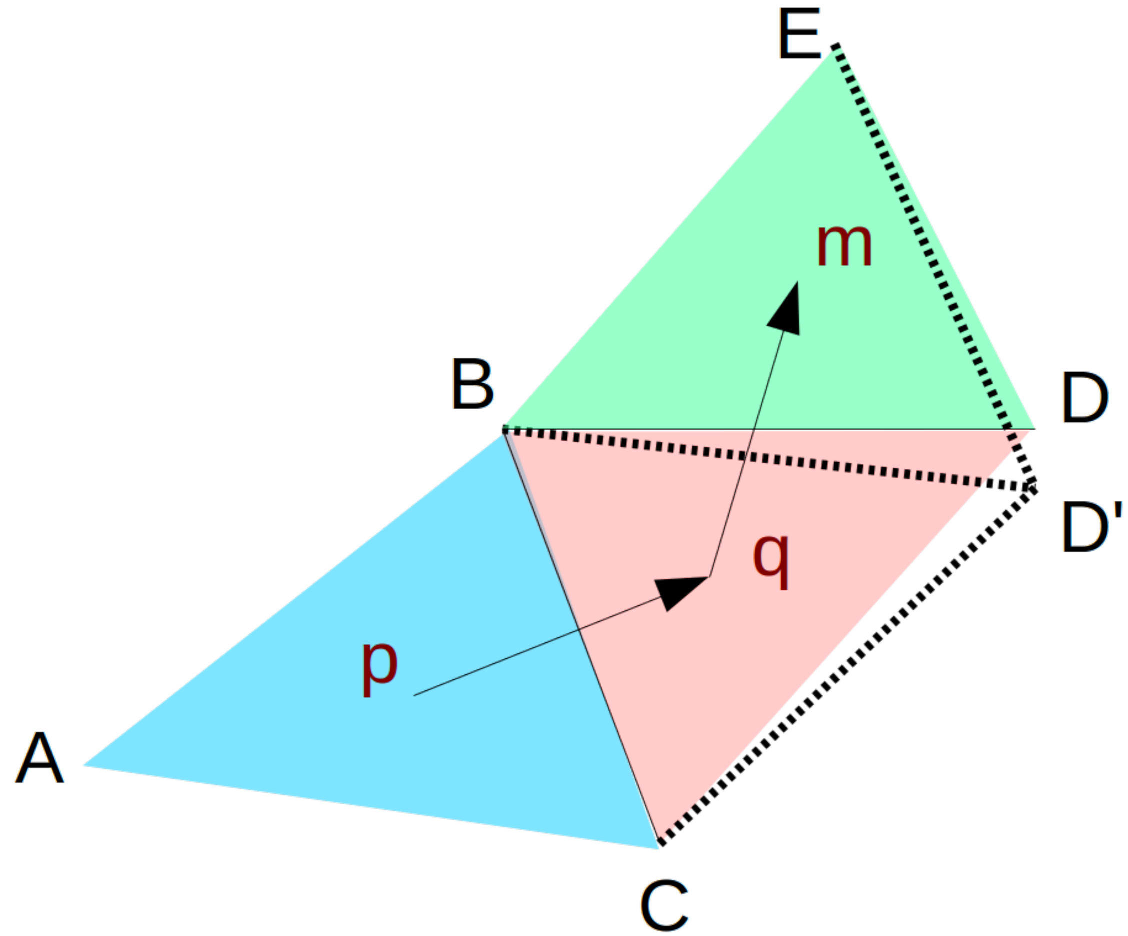


Quantization

- Optimal bits difference

$$b_{rh} = b_\theta - \lfloor 0.5 - \log_2(\sigma) \rfloor$$

- Naive implementation
- Compensate the accumulation error



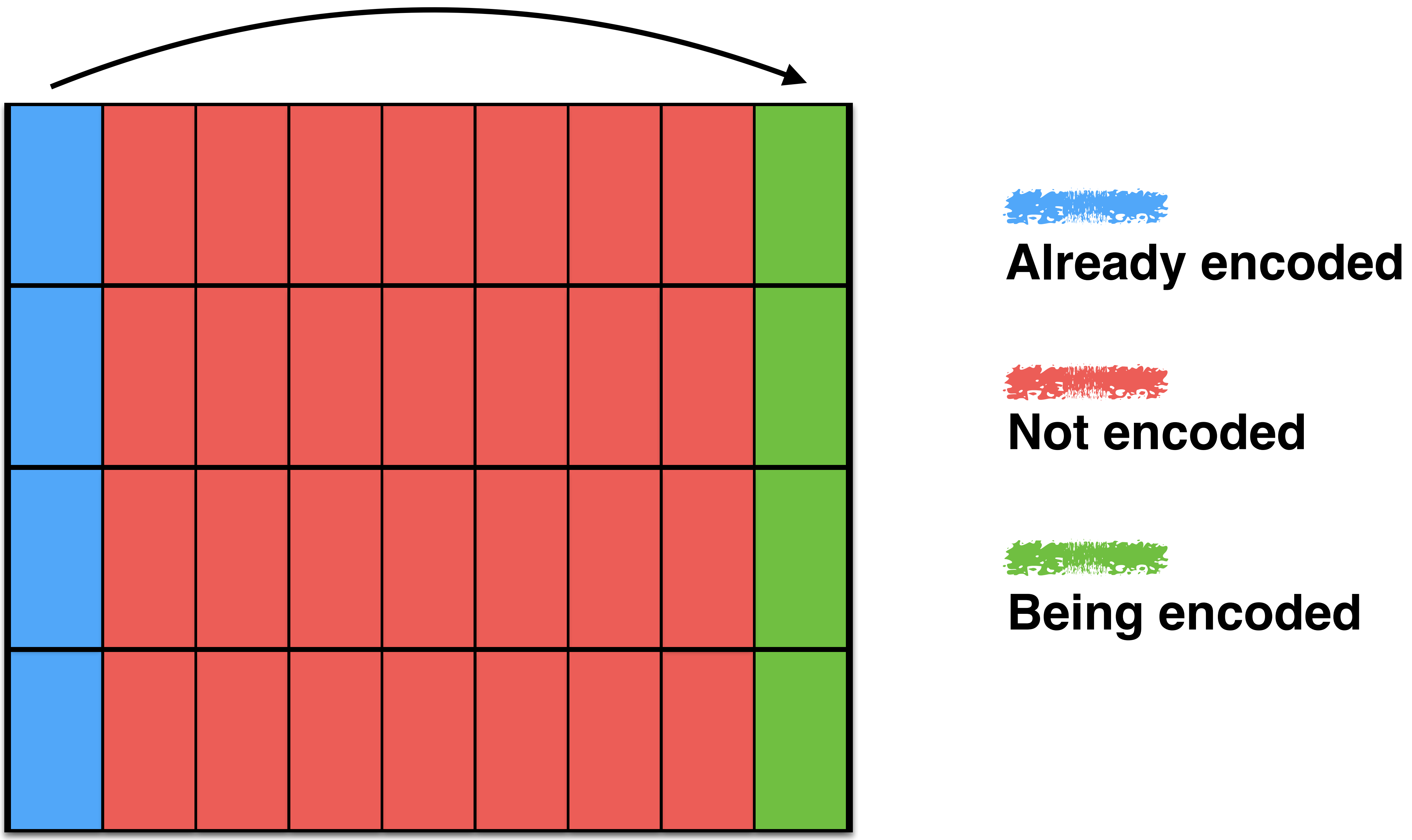
Temporal Prediction

Already encoded

Not encoded

Being encoded

Temporal Prediction



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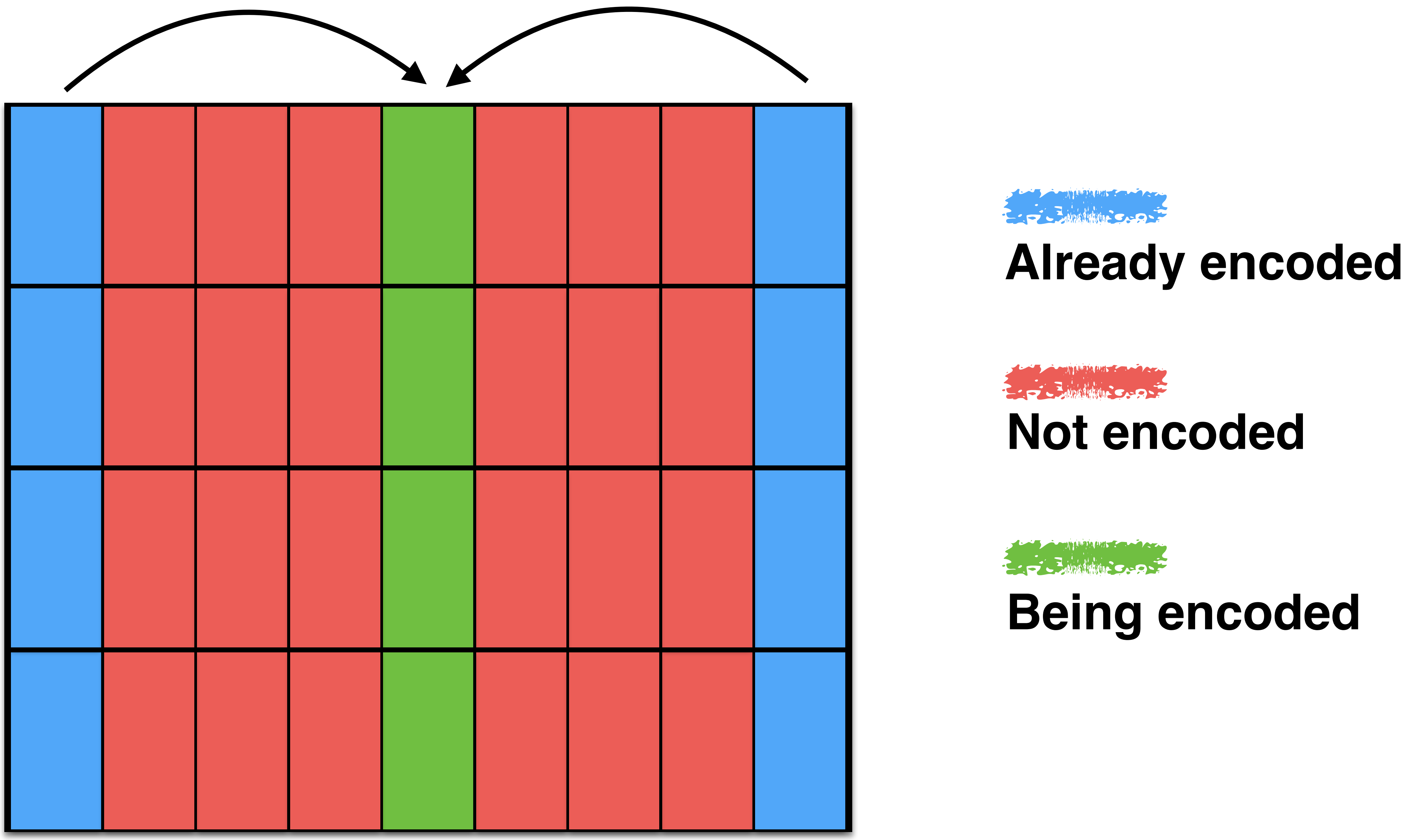

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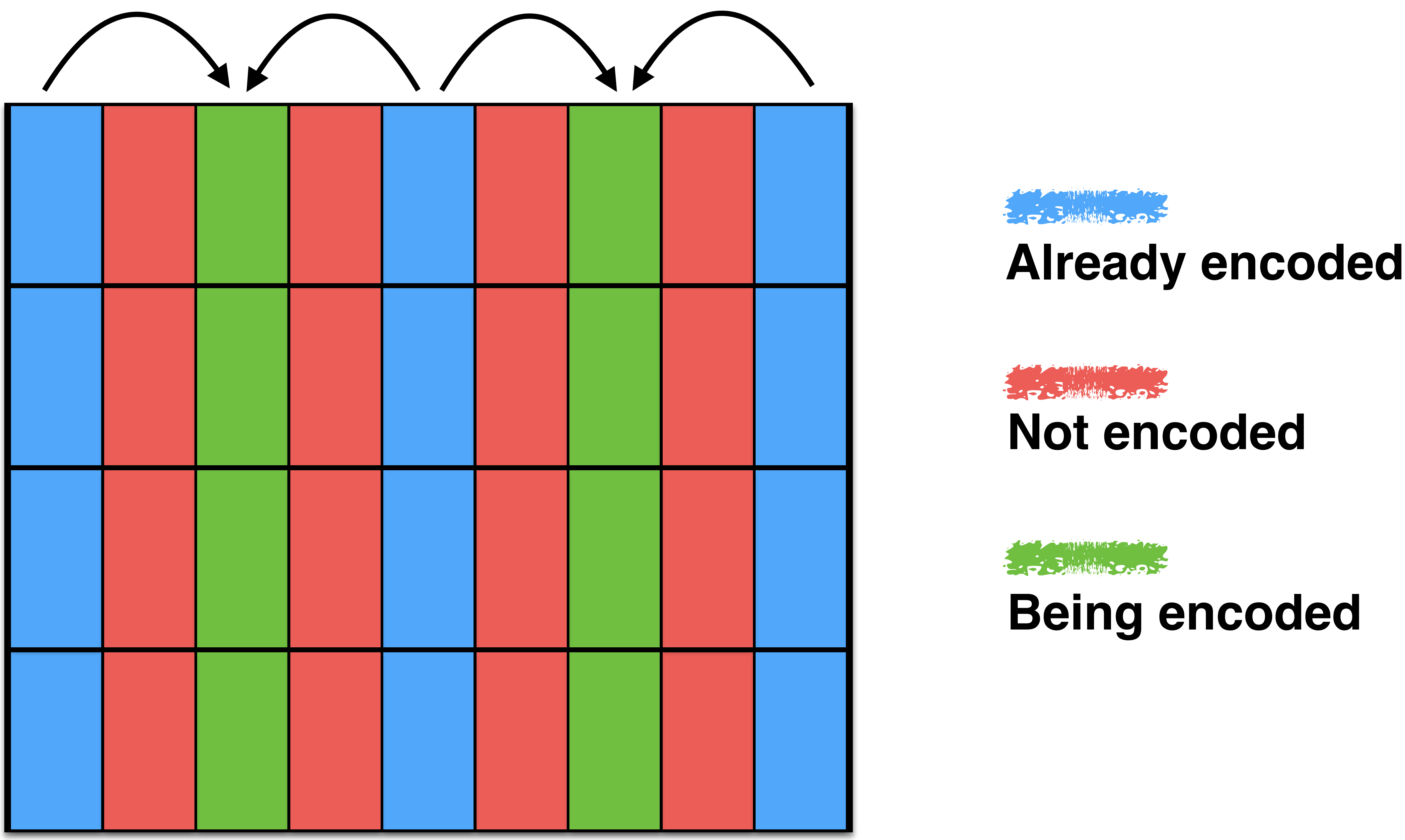

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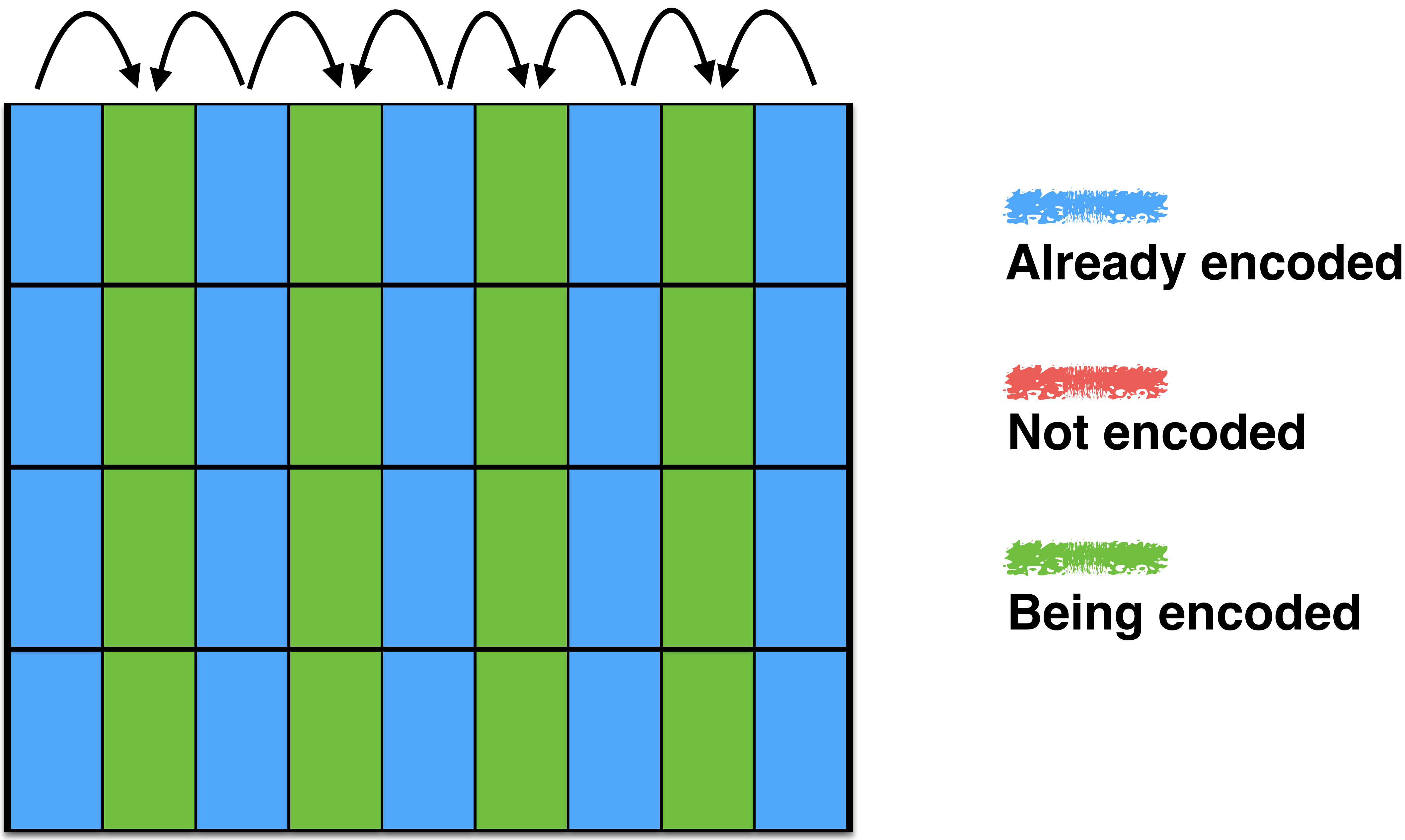
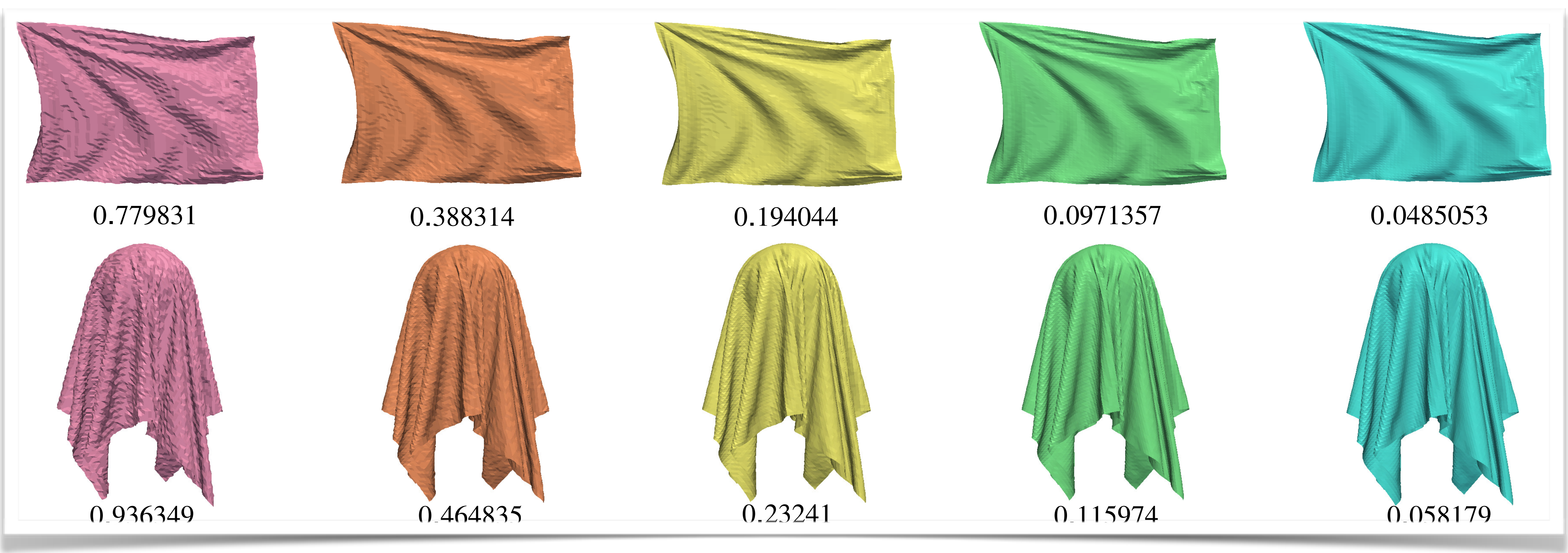


Results

- Quality metric: KG error [Karni et al. 04]

$$e_{KG} = 100 \frac{\|\mathbf{F} - \hat{\mathbf{F}}\|}{\|\mathbf{F} - \mathbf{E}(\mathbf{F})\|}$$

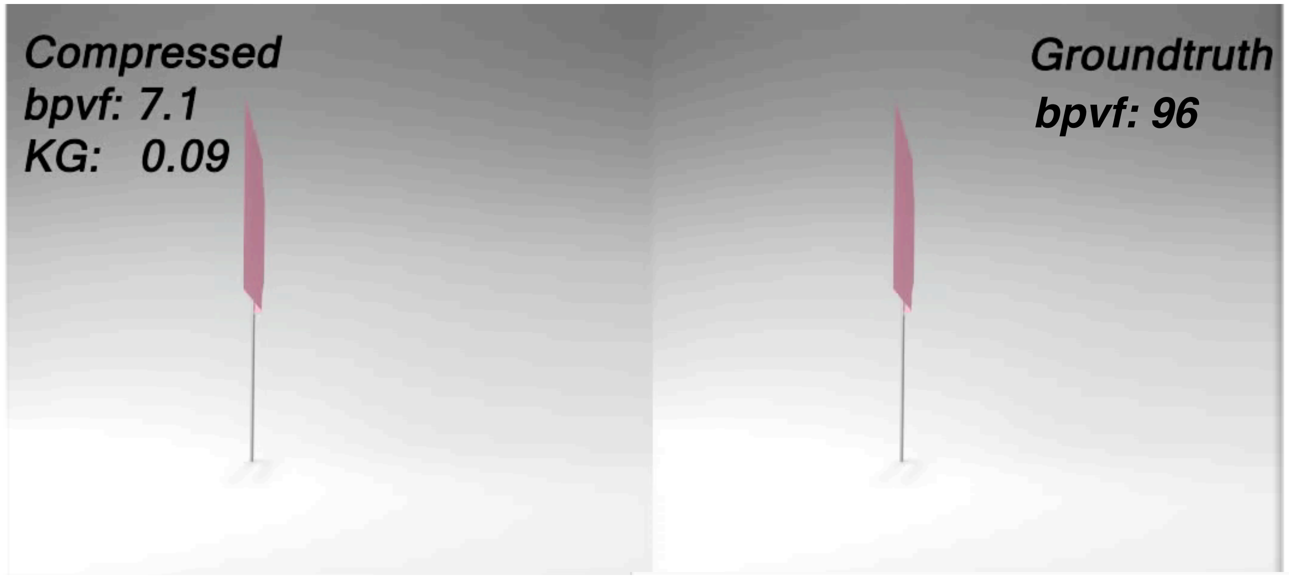
- Error on visual appearance



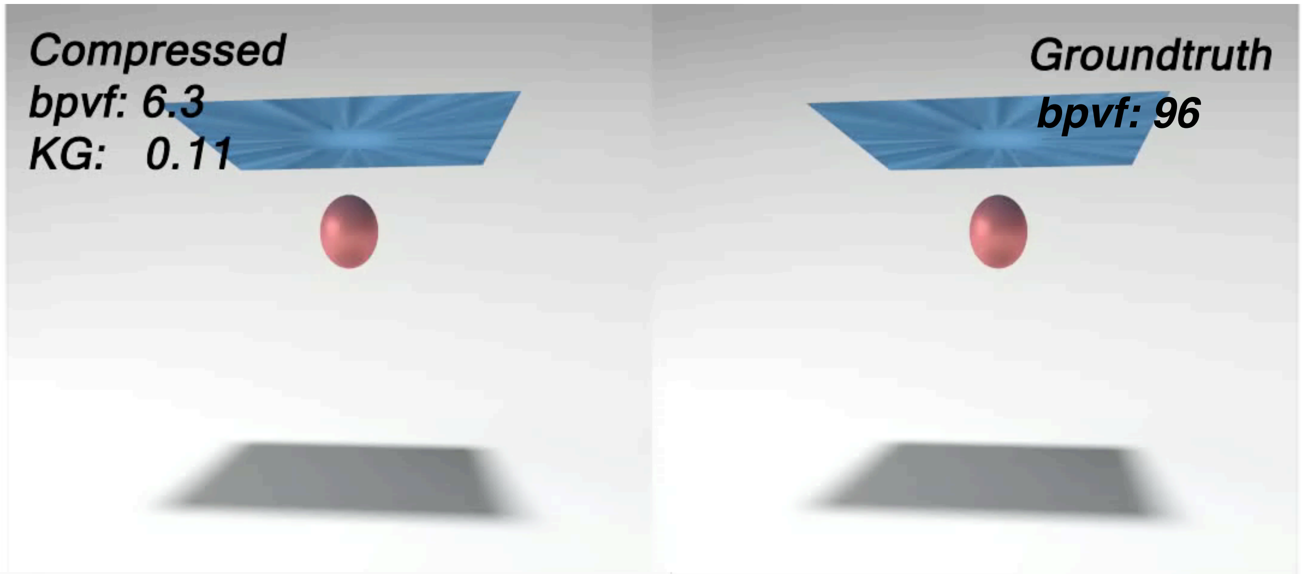
Results

- Bpvf: bits per vertex frame
  - 96 (3 components x 4 bytes x 8 bits) for uncompressed animation

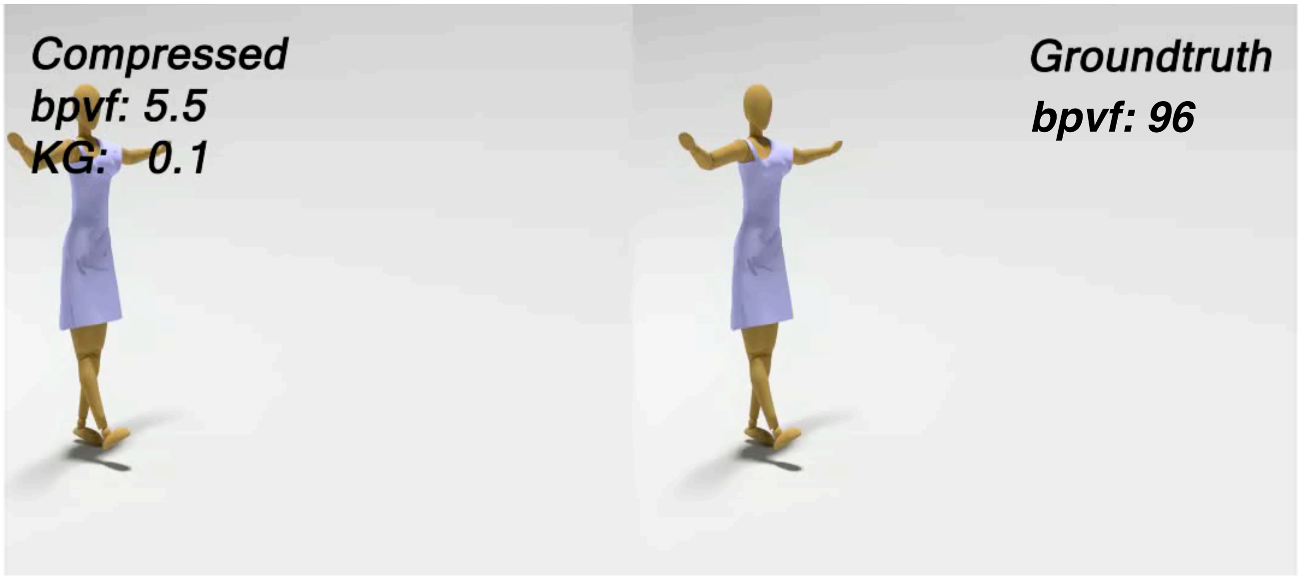
Results



windy flag

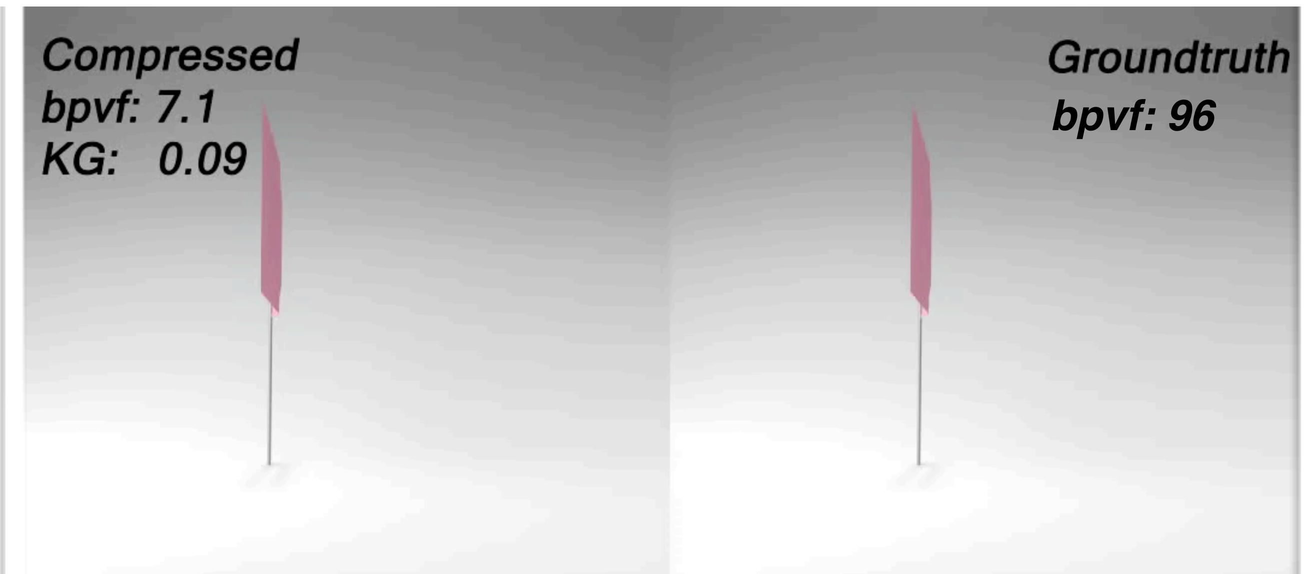


falling cloth

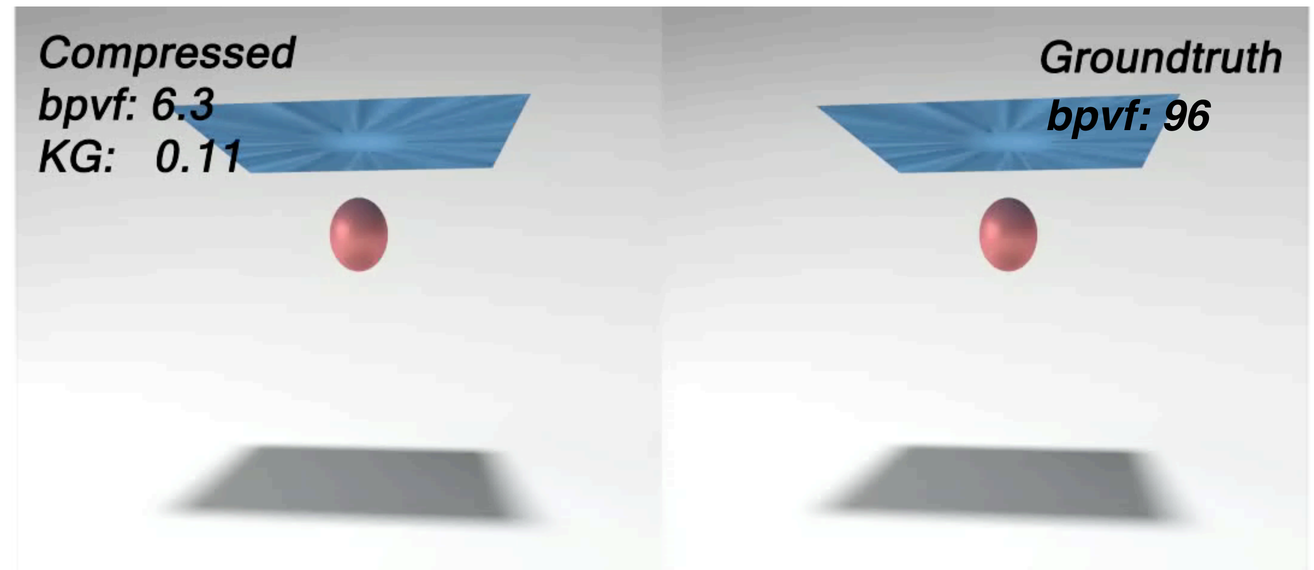


dress

Results



windy flag



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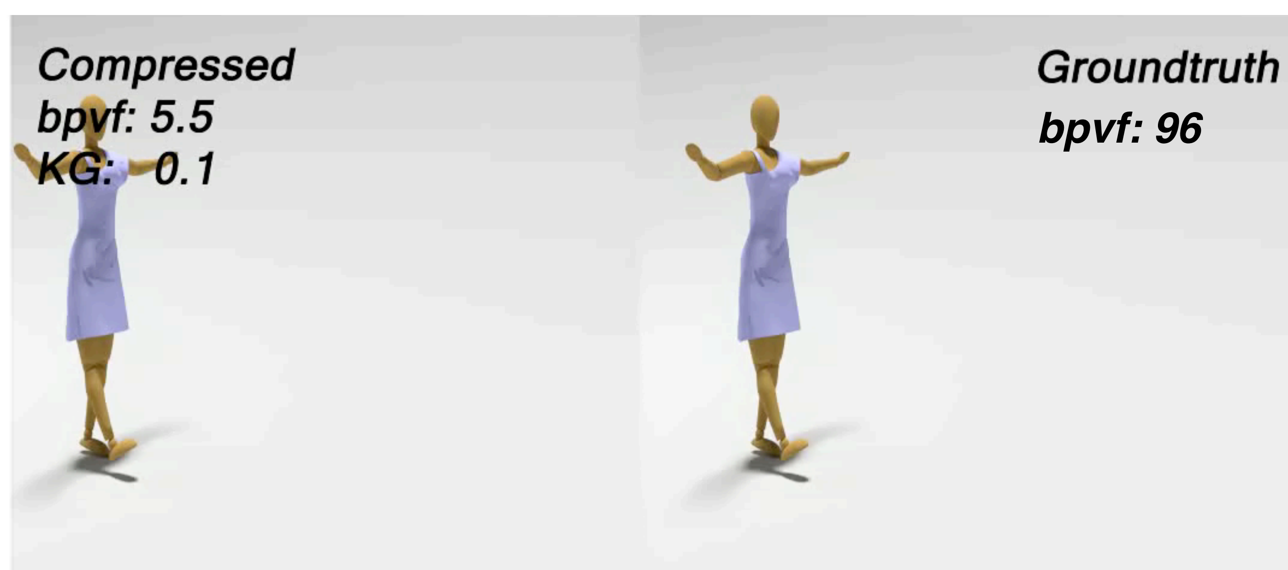
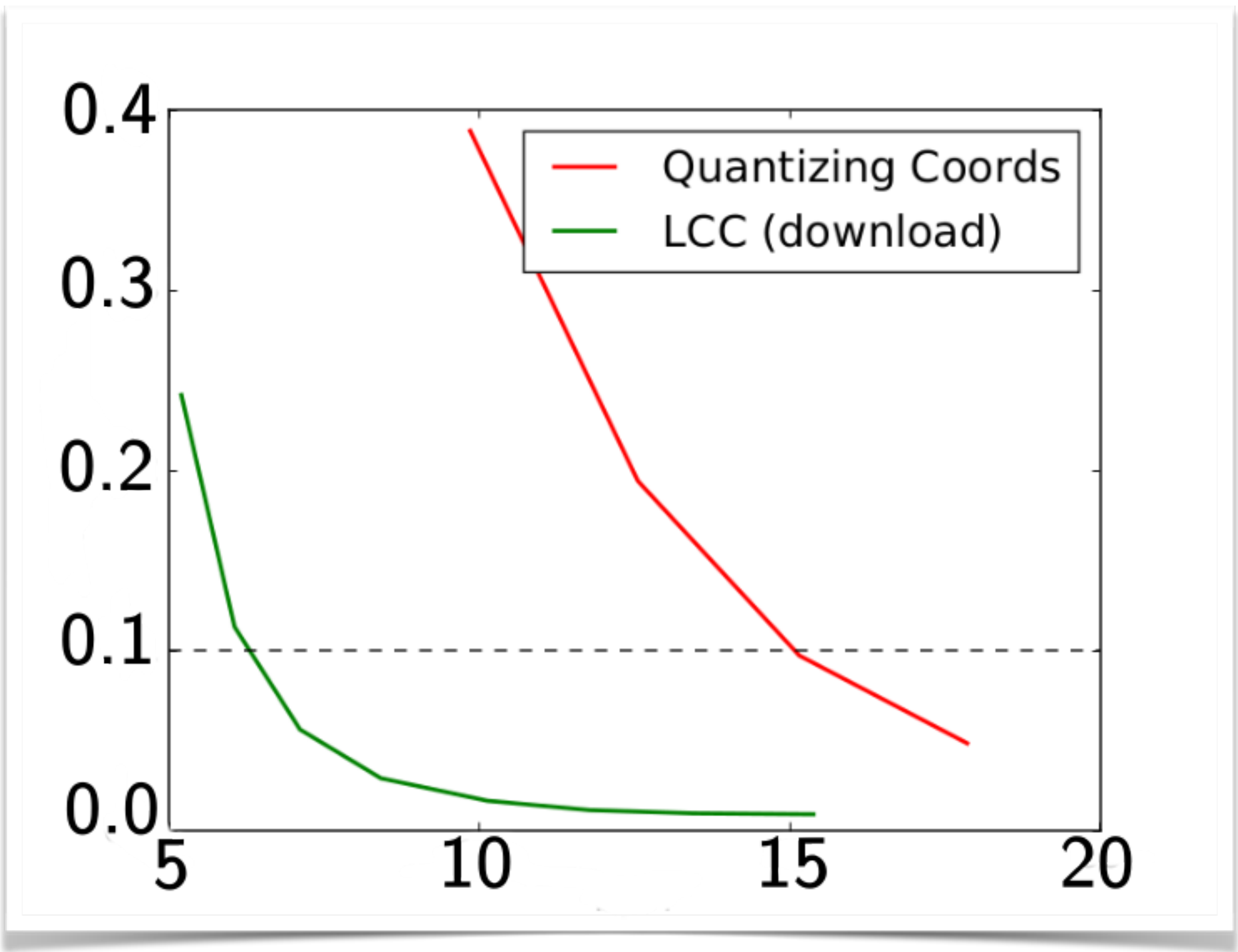


dress

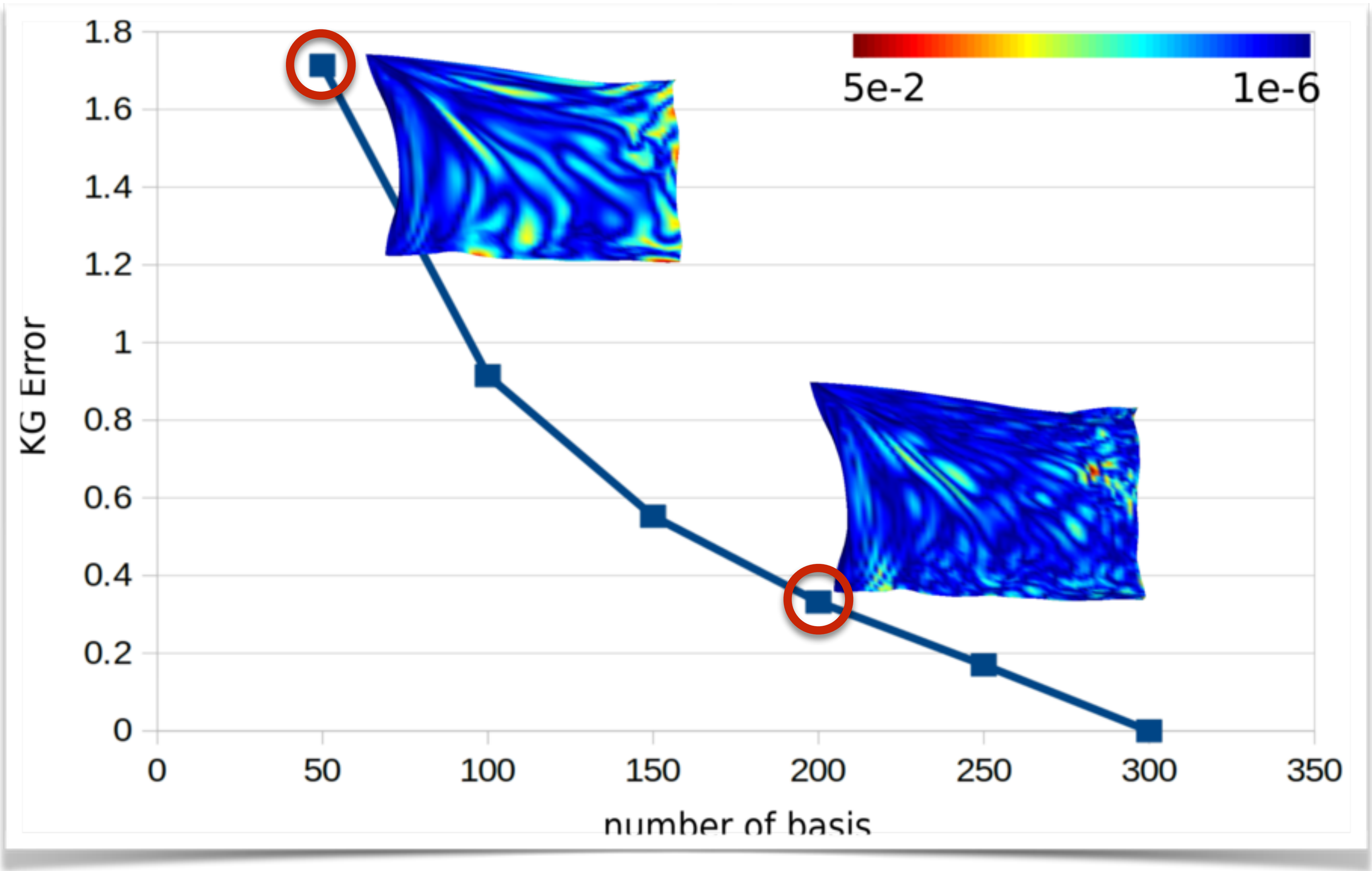
Results

- With directly quantizing Euclidean coordinates



Comparisons

- For spectral method [Alexa et al. 00]



Results

- With SPC
  [Stefanoski et al.10]

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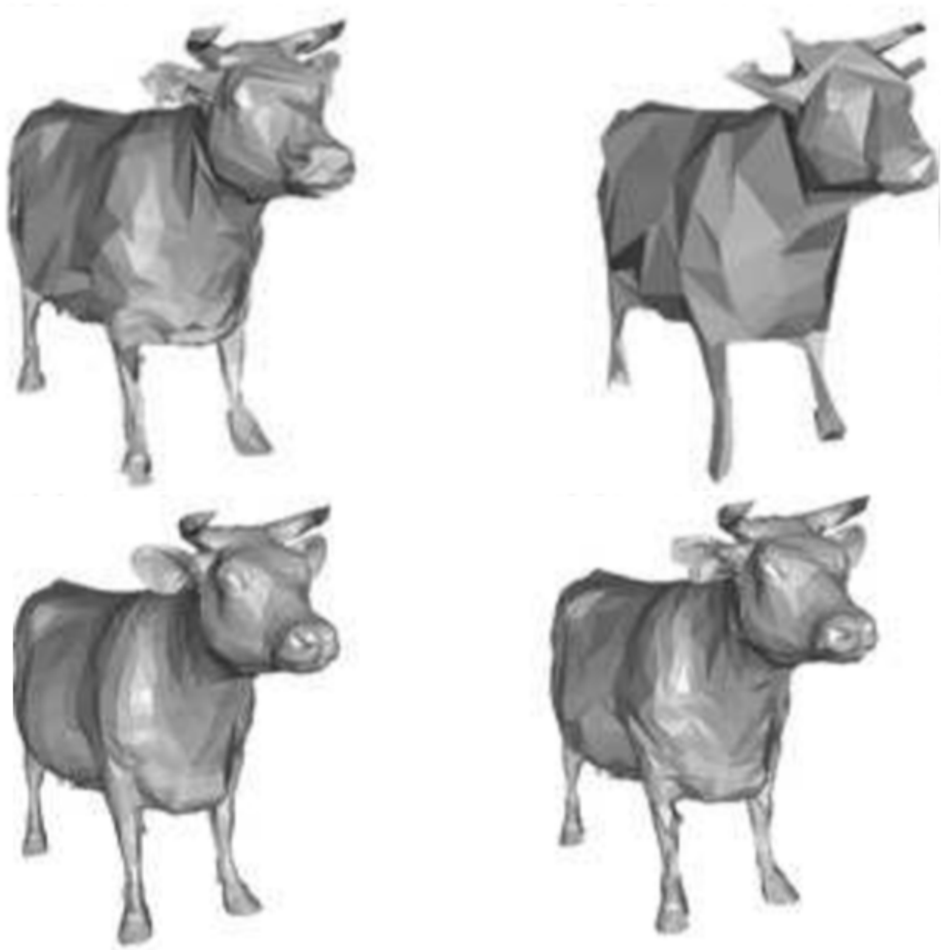

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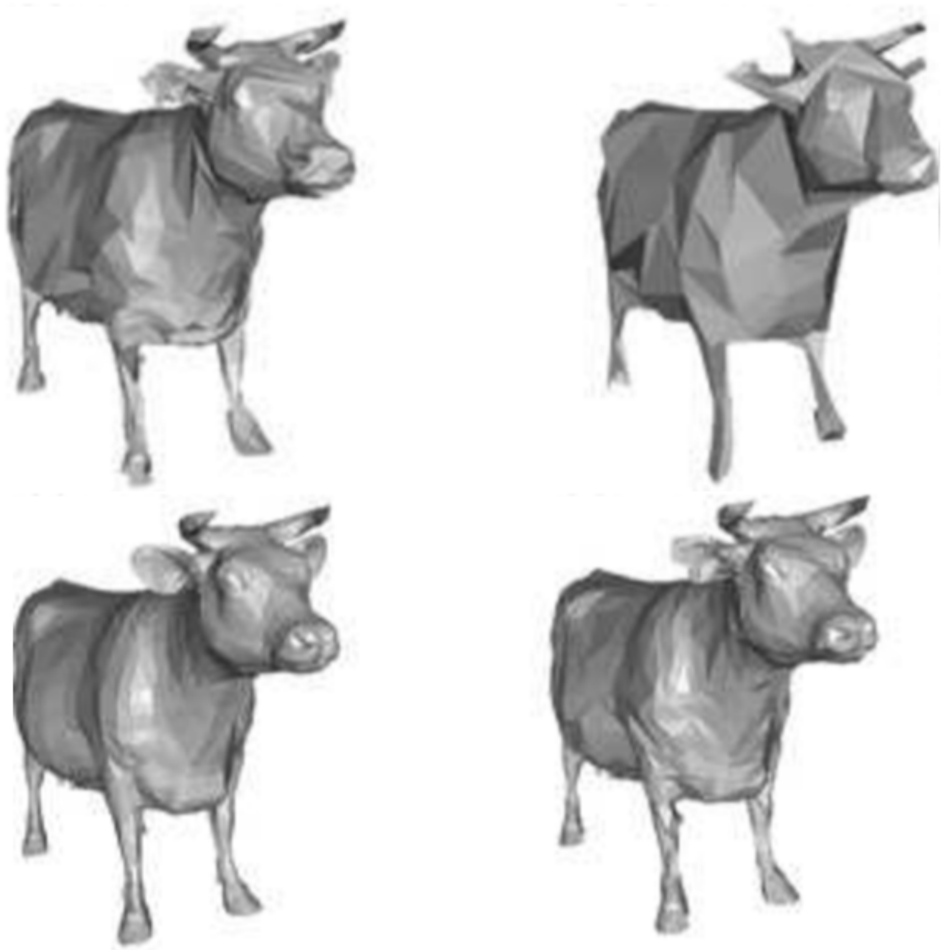
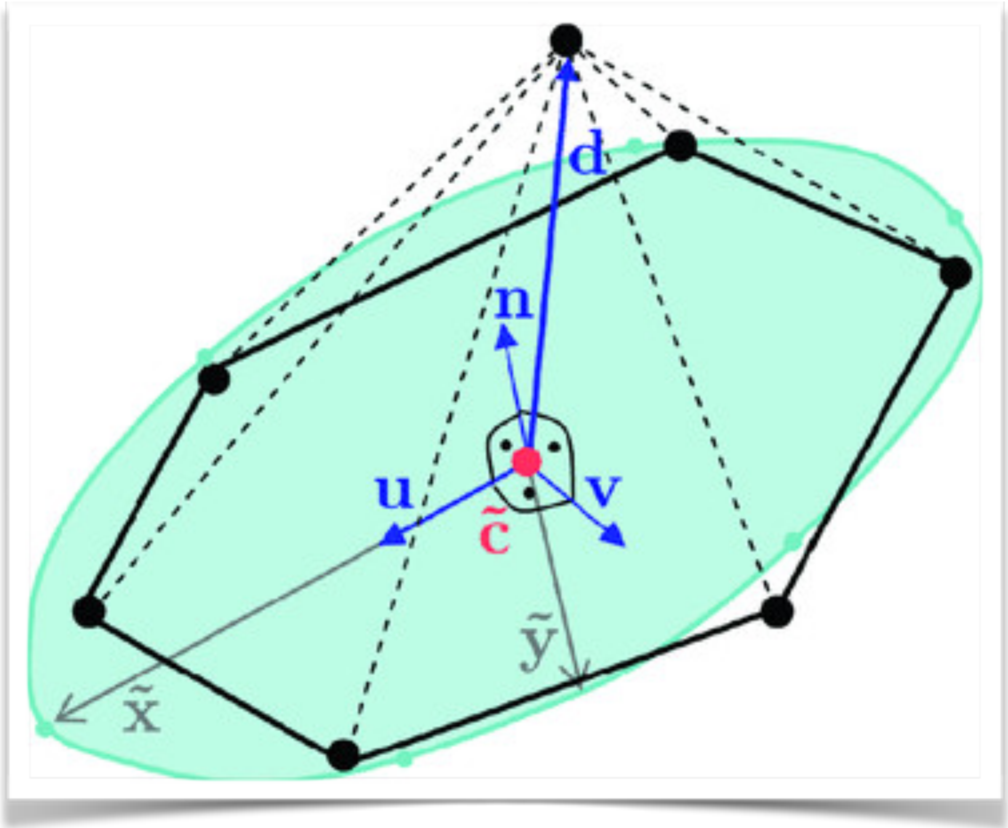
  [Stefanoski et al.10]

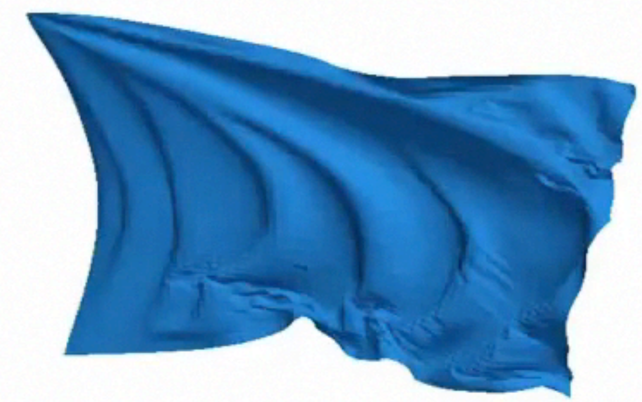




Results

temporal resolution = 9

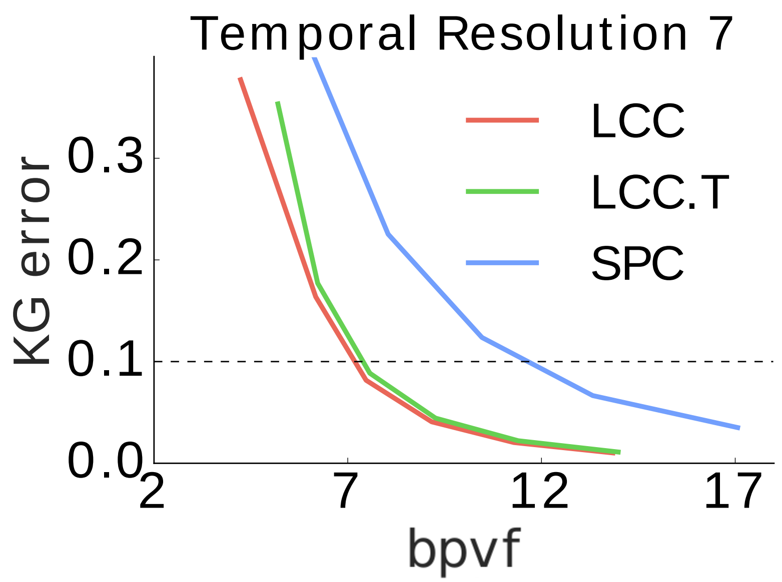
temporal resolution = 10

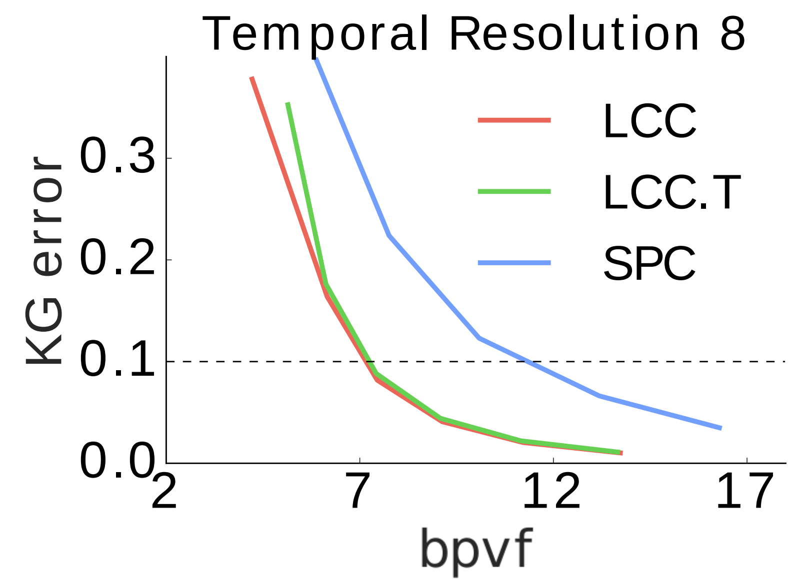


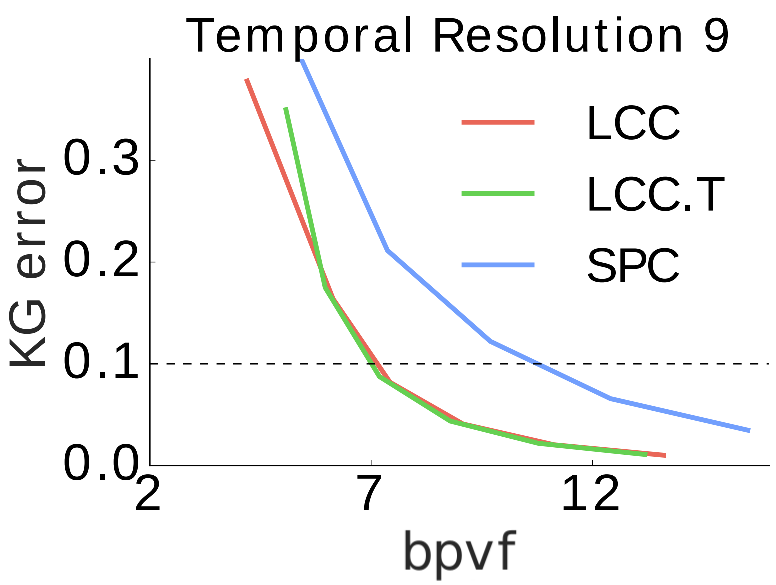
temporal resolution = 11

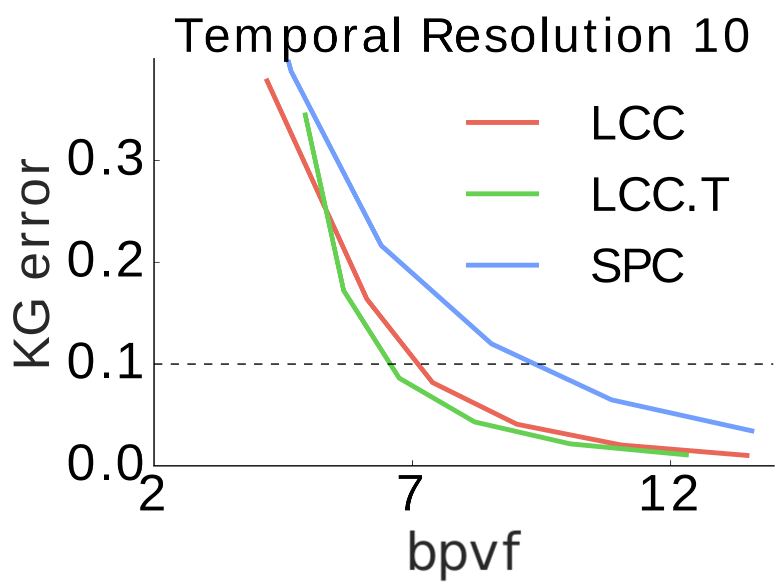
Results

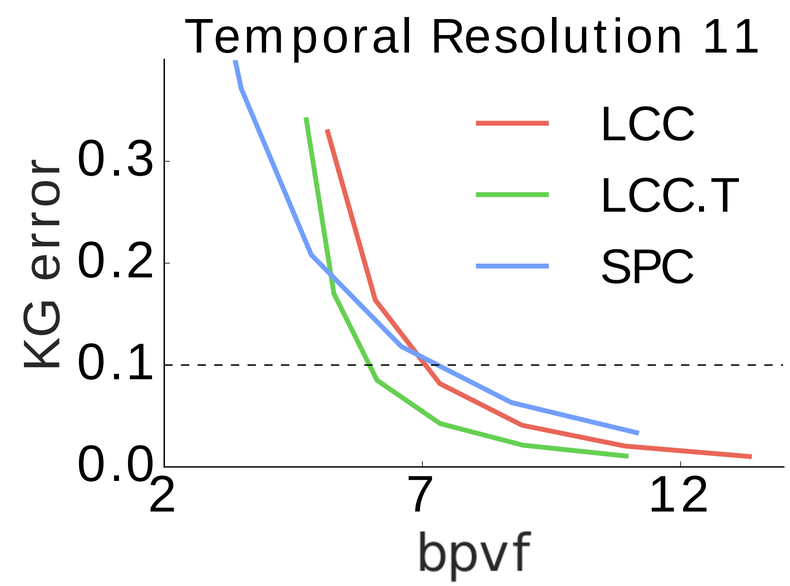
- With SPC [Stefanoski et al.10]











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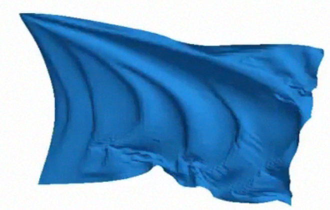

temporal resolution = 11

Timings

animation	windy flag	falling cloth	dress
#vert	4225	16641	104482
#frms	300	250	300
comp. time (s)	1.13	3.61	32.0
decomp. time (s)	1.0	2.6	27.0
comp. #vert/ms	1118	1154	980
decomp. #vert/ms	1268	1600	1161

Timings

animation	windy flag	falling cloth	dress
#vert	4225	16641	104482
#frms	300	250	300
comp. time (s)	1.13	3.61	32.0
decomp. time (s)	1.0	2.6	27.0
comp. #vert/ms	1118	1154	980
decomp. #vert/ms	1268	1600	1161

Future Work

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- Compression of adaptively remeshed simulation

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- Compression of adaptively remeshed simulation
- Determine optimal bits with prescribed KG error
- More powerful temporal prediction

Thank you!