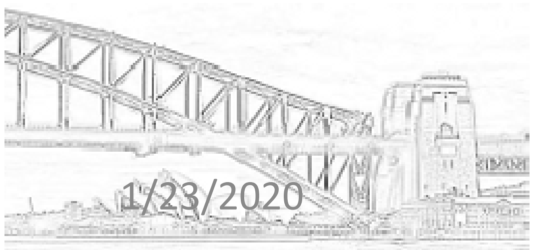
Anim-DoG: A Spatio-Temporal Feature Point Detector for Animated Mesh

Vasyl Mykhalchuk[*], Hyewon Seo[*], Frédéric Cordier[‡]

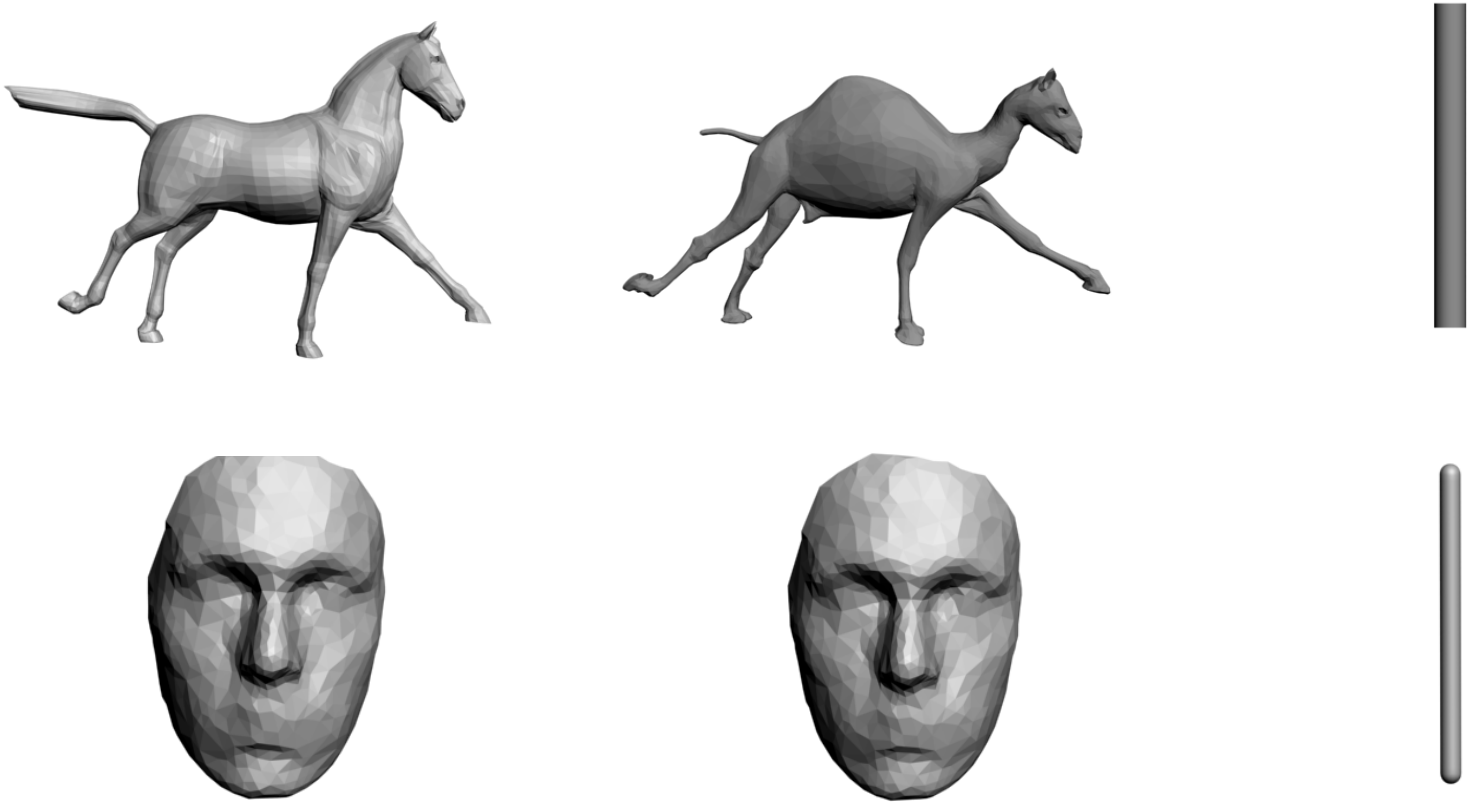
[*]Université de Strasbourg, France
[‡]Université de Haute Alsace, France



CGI'14

31st Computer Graphics International
10 - 13 June 2014
Sydney, Australia

Animated Mesh



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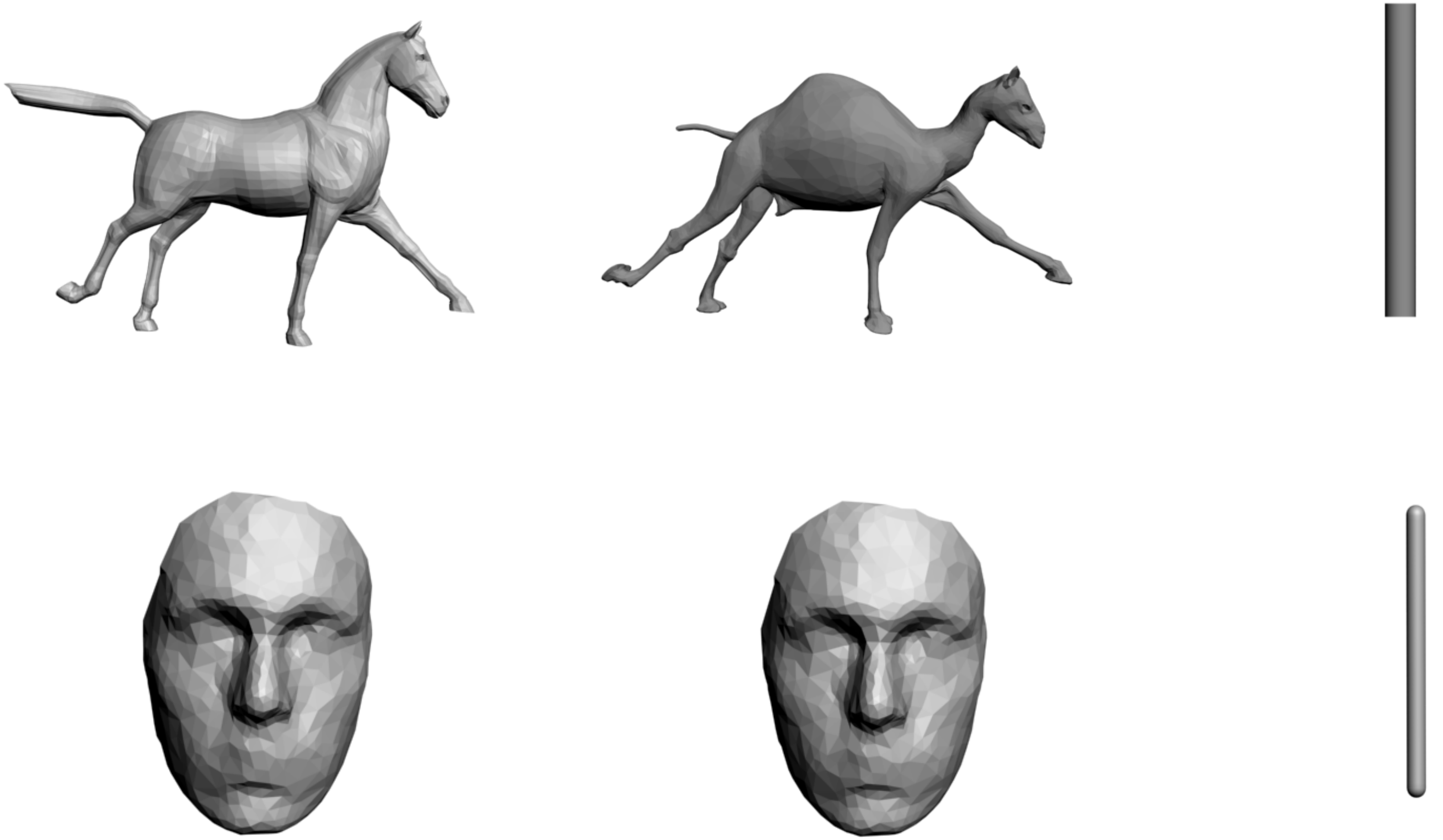
Animated Mesh



Assumption: fixed number of vertices and triangulation

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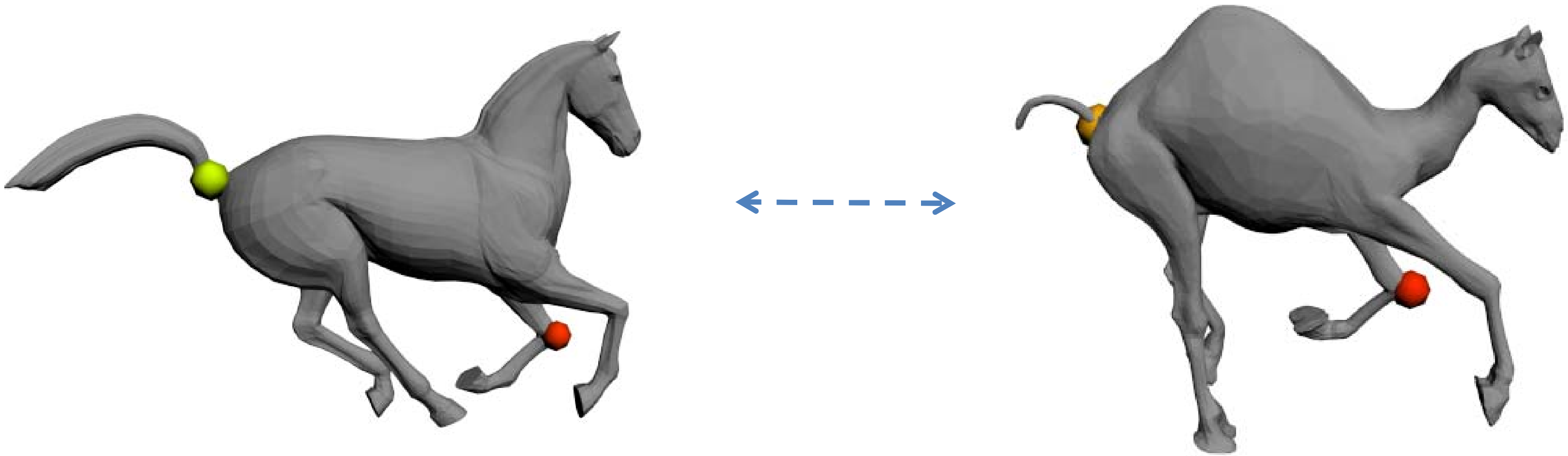
Animation Feature Points



	Well studied
Image/Video/Static mesh	Yes
Deforming mesh	No

- Animation matching
- Temporal alignment
- Animation viewpoint selection

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Related works

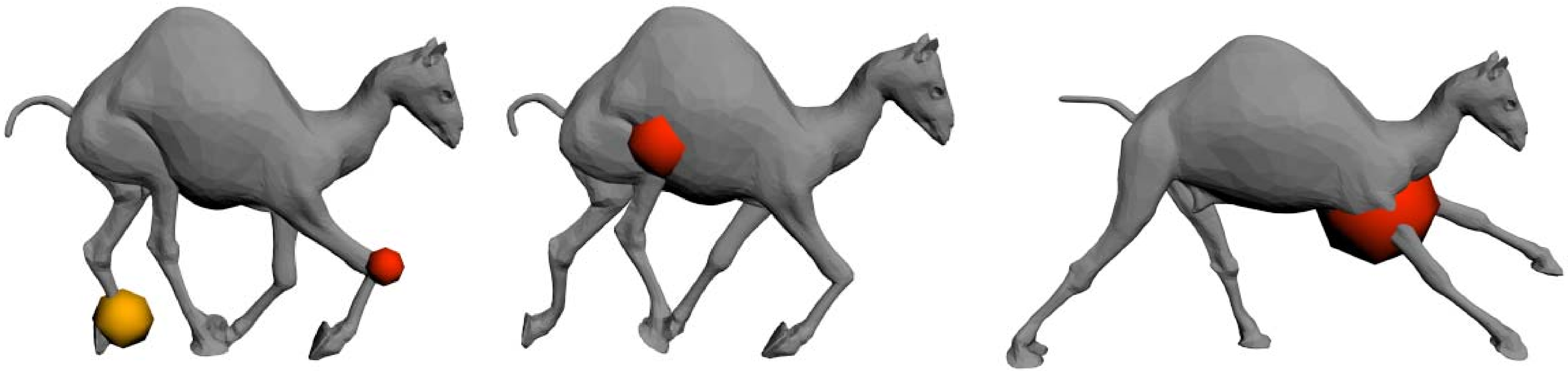
Image

- [Mikolajczyk and C. Schmid ’01] **Harris + Laplacian operators**
- [Laptev and Lindeberg ’03] **Scale-normalized Laplacian operator**

Static mesh

- [Pauly et al. ‘03] **Multi-Scale Surface Variation**
- [Castellani et al. ‘08] **Difference-of-Gaussians operator (DoG) on vertex coordinates**
- [Zaharescu et al. ‘09] **DoG on vertex scalar field**
- [Darom and Keller ‘12] **Density invariant DoG**

Animation Feature Points



Properties:

- Spatio-temporal
- Rigid transformation invariant
- Multiscale
- Consistent

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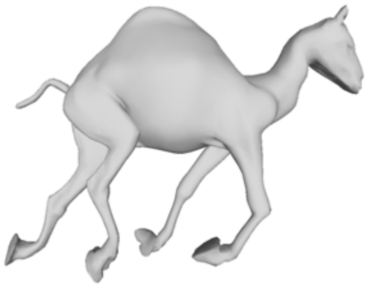
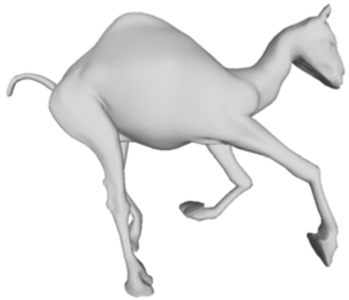
The Setup

- **Given**:

$\mathcal{M}=\{F_1, \ldots, F_M\}$

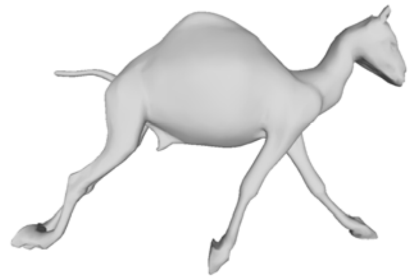


F_1



F_2

…

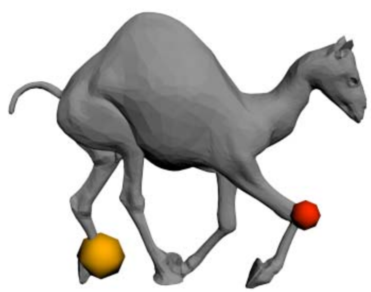


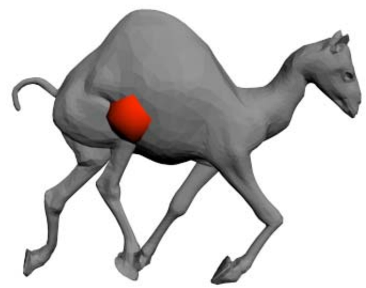
F_M

- **Output**:

  Detect animation feature points:

  $P=\{(p_i, \sigma_i, \tau_i)\}$





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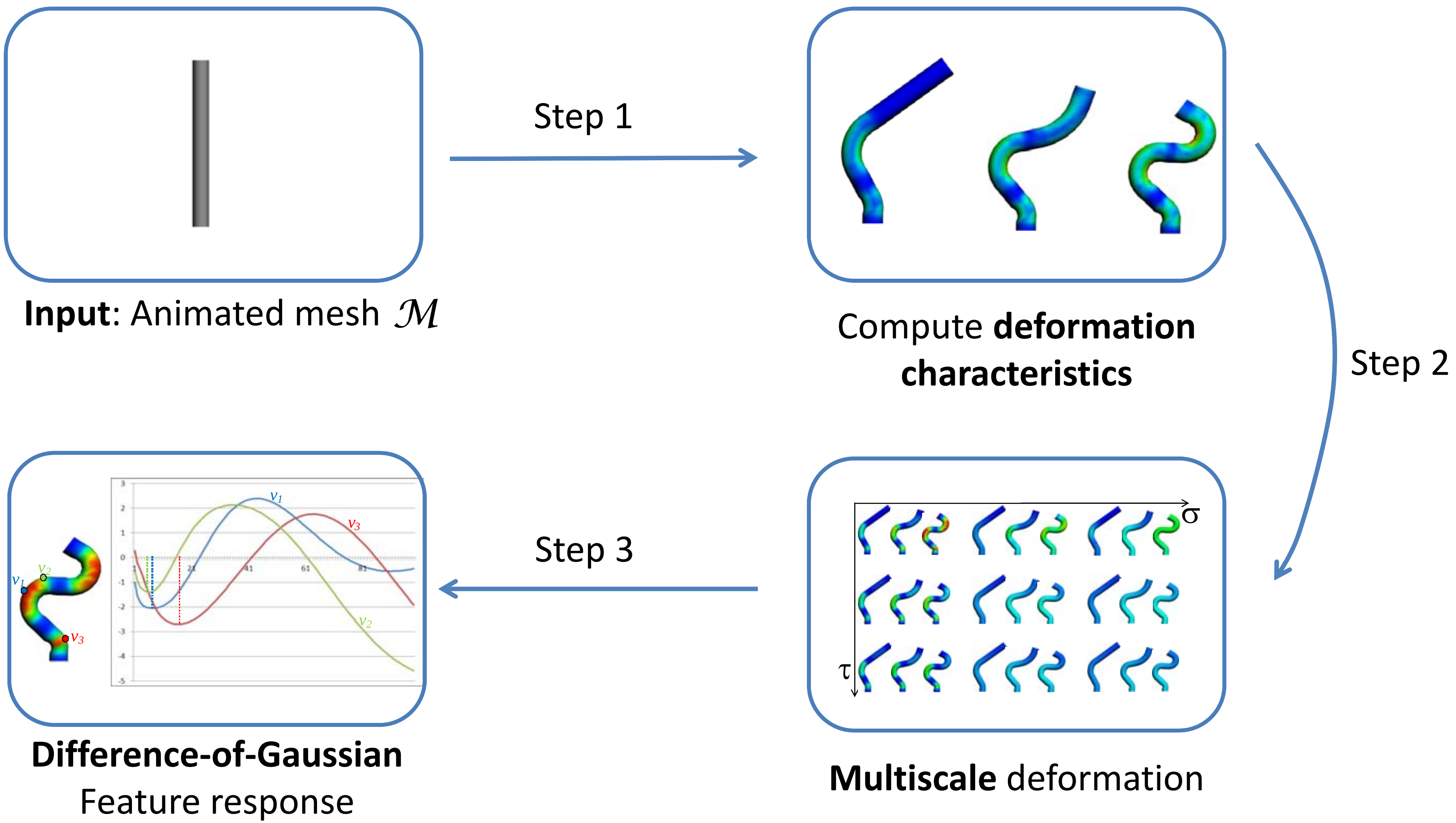
Pipeline overview



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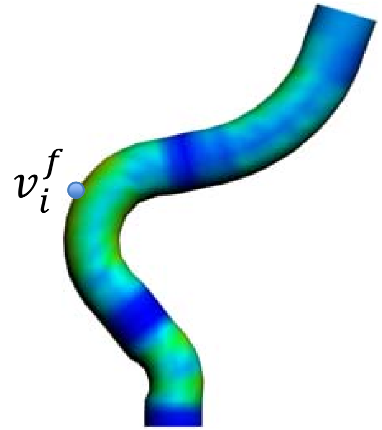
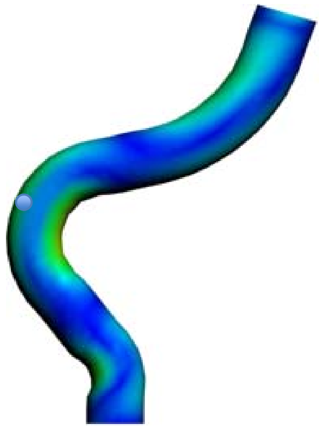
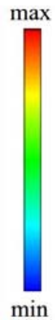
Step 1: Deformation Characteristics

- Strain $s(v_i^f)$



- Curvature change $\Delta c(v_i^f)$





Per-trinagle strain/stretch [Luo et al.' 14]

↓

Per-vertex strain/stretch

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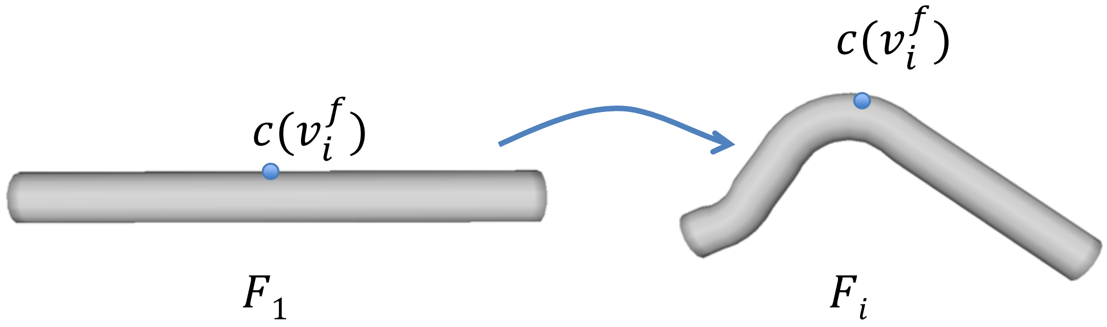
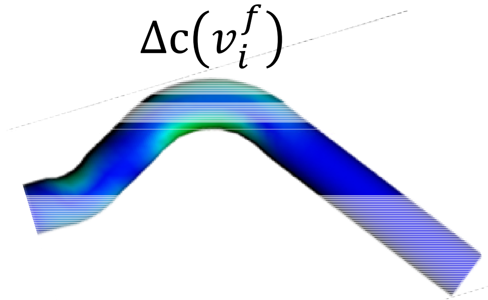
Curvature change





Mean curvature change $$\Delta c(v_i^f) = |c(v_i^f) - c(v_i^1)|$$

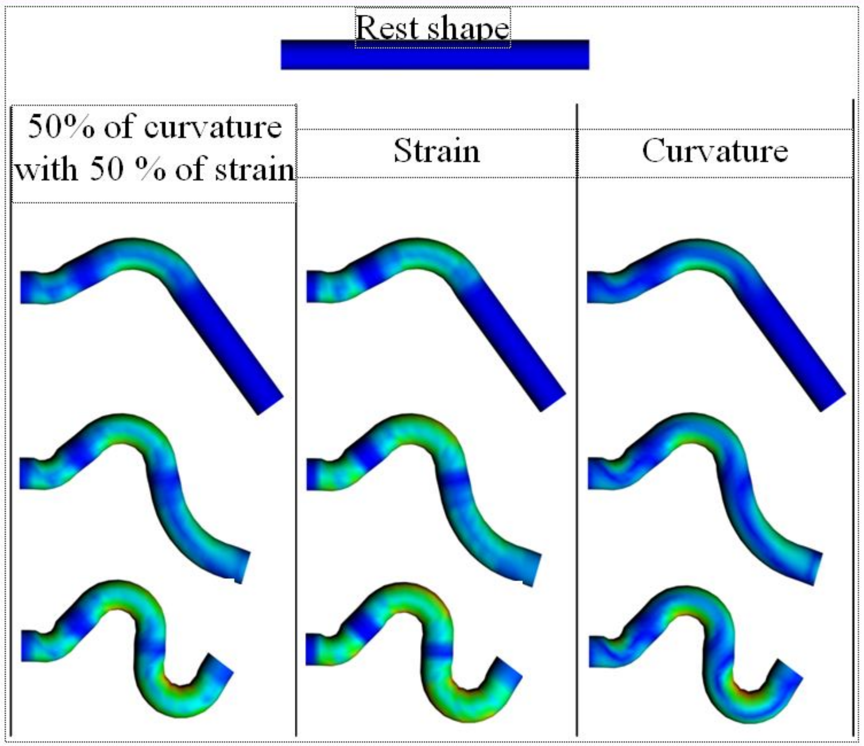
[ACD*03] P. Alliez, D. Cohen-Steiner, O. Devillers, B. Levy, and M. Desbrun: Anisotropic Polygonal Remeshing, ACM Transactions on Graphics, 2003.

Deformation Characteristics

$$d(v_i^f) = \alpha \cdot s(v_i^f) + (1-\alpha) \cdot |c(v_i^f) - c(v_i^1)|$$

Strain

Curvature change



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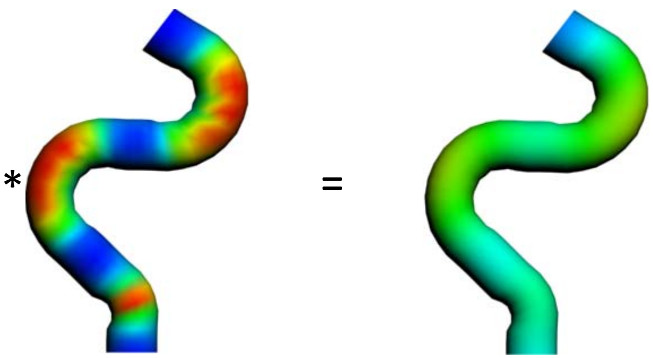
Multiscale representation

- **Surface deformation structures at different scales**
- **Handle Noise**

- Convolution of d with Gaussian kernels of variance σ^2 and τ^2

$L(\mathbf{x}, t; \sigma, \tau)$ = g($\mathbf{x}$, t, σ^2, τ^2) * d($\mathbf{x}$, t)

g($\mathbf{x}$, t, σ^2, τ^2) *  =

d($\mathbf{x}$, t) $L(\mathbf{x}, t; \sigma, \tau)$

Deformation characteristic

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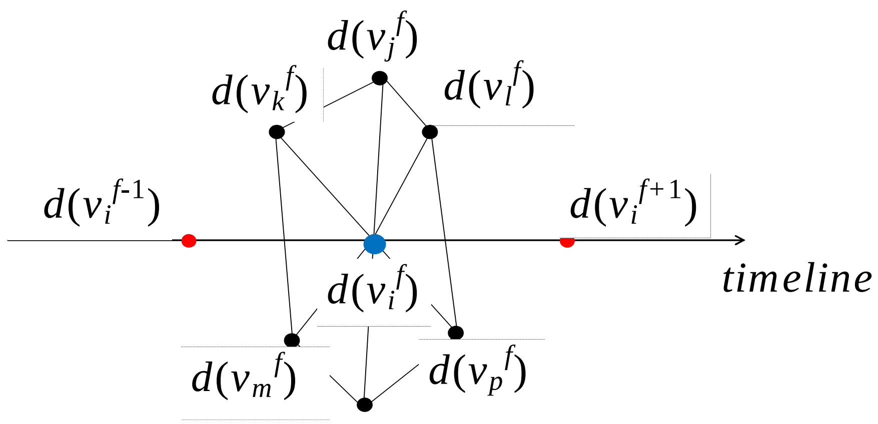
Multiscale representation

- Moving average approximation
- Equivalent to Gaussian smoothing with $\sigma = \sqrt{\frac{n(w^2-1)}{12}}$

w- average edge length



[AC92] R. Andonie, E. Carai: Gaussian Smoothing by Optimal Iterated Uniform Convolutions, Computers and Artificial Intelligence, 11(4): pp. 363-373, 1992.

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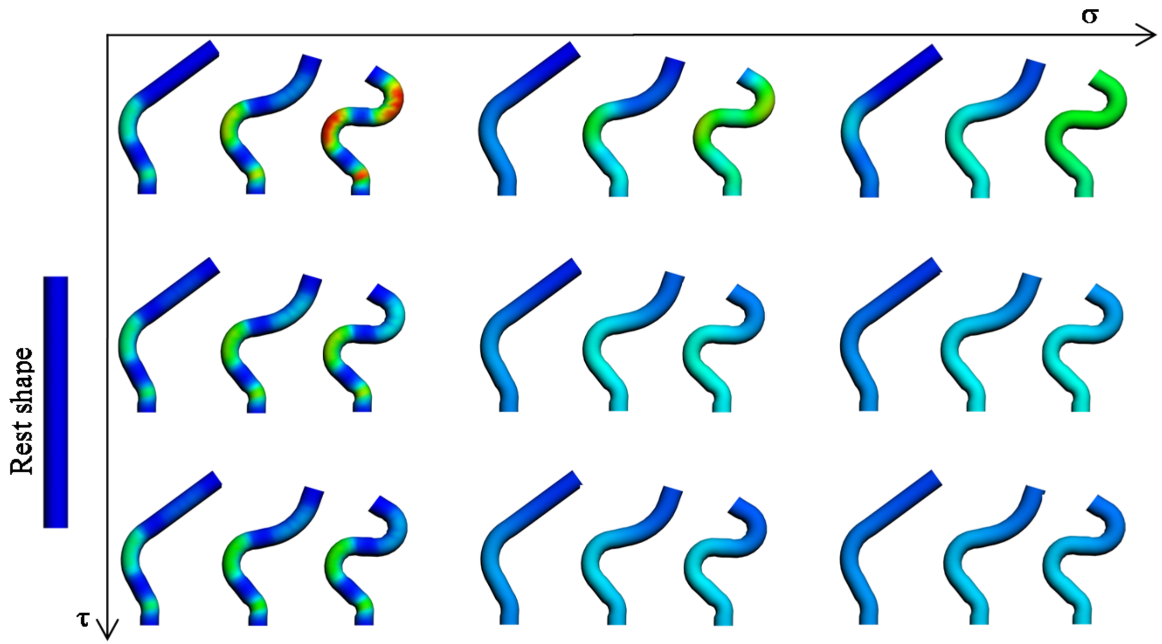
Multiscale representation

$L_{ij}(i \in \Sigma=0,\ldots N,\ j \in \mathrm{T}=0,\ldots K)$

octave scale	σ_1	σ_2	…	σ_N
τ_1	L_{11}	L_{12}	…	L_{1N}
τ_2	L_{21}	L_{22}	…	L_{2N}
⋮	⋮	⋮		⋮
τ_K	L_{K1}	L_{K2}	…	L_{KN}

(a) Multi-scale deformation characteristics



(b) Visual representation

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Feature Response

- **Space-time Difference-of-Gaussians**

$$D_{\text{spacetime}}(\mathbf{x}, t; \sigma, \tau) = \text{Dspace}(\sigma) + D_{\text{time}}(\tau)$$

Detect centers of deformation blobs

$$D_{\text{space}}(\sigma) = L(\sigma + 1) - L(\sigma)$$

$$D_{\text{time}}(\tau) = L(\tau+1) - L(\tau)$$

- **Approximates Laplacian**

mykhalchuk@unistra.fr

Feature Response

Space-time Difference-of-Gaussians

- Scale normalize

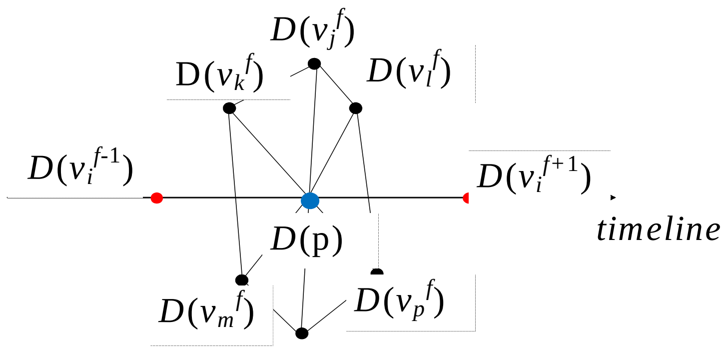
$$D_{\mathrm{spacetime}}(\mathbf{x}, t; \sigma, \tau) = \sigma^2\tau^{1/2} D_{\mathrm{space}}(\mathbf{x}; \sigma) + \sigma\tau^{3/2} D_{\mathrm{time}}(t; \tau)$$

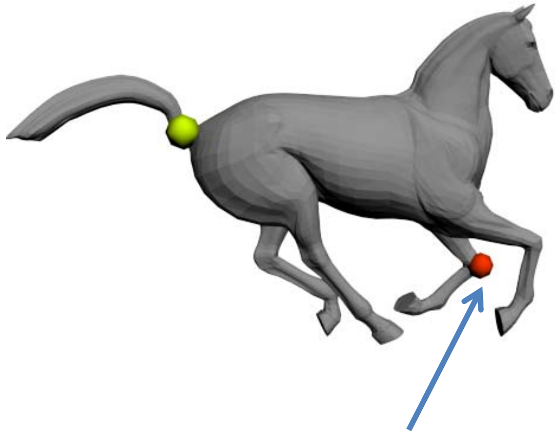
Detect centers of deformation blobs

Feature Detection Algorithm

- **Local minima in space-time (intra-octave)**

$$P = \{p \in \mathcal{M} |\ \forall p_i \in \mathcal{N}_{st}(p), D(p) < D_{kl}(p_k) \text{ and } D(p) < \varepsilon_{st}\},$$





(p, σ, τ)

- **Local minima in scale (inter-octave)**

$$P = \{p \in \mathcal{M} | \forall (i,j) \in \mathcal{N}_{\sigma\tau}, D_{ij}(p) > D(p) \text{ and } D(p) < \varepsilon_{\sigma\tau}\}$$

$D_{\sigma-1\tau-1}$	$D_{\sigma\tau-1}$	$D_{\sigma+1\tau}$
$D_{\sigma-1\tau}$	$D_{\sigma\tau}$	$D_{\sigma+1\tau}$
$D_{\sigma-1\tau}$	$D_{\sigma\tau+1}$	$D_{\sigma+1\tau+1}$

mykhalchuk@unistra.fr

Experiments

Name	# vertices/ triangles	# frames	Filter widths (space/time)	Max. no. smoothings (space/time)
Cylinder	587/1170	40	10.0/0.83	50/100
Face1 Happy	608/1174	139	8.96/8.45	118/113
Face1 Surprise	608/1174	169	9.39/13.2	96/107
Face2 Happy	662/1272	159	9.31/13.2	112/94
Face2 Surprise	662/1272	99	8.95/8.45	109/57
Galloping Horse	5000/9984	48	3.48/5.33	77/54
Galloping Camel	4999/10000	48	2.62/5.33	102/54

~2 min (Intel Core i7–2600 3.4 GHz, 16 GB RAM)

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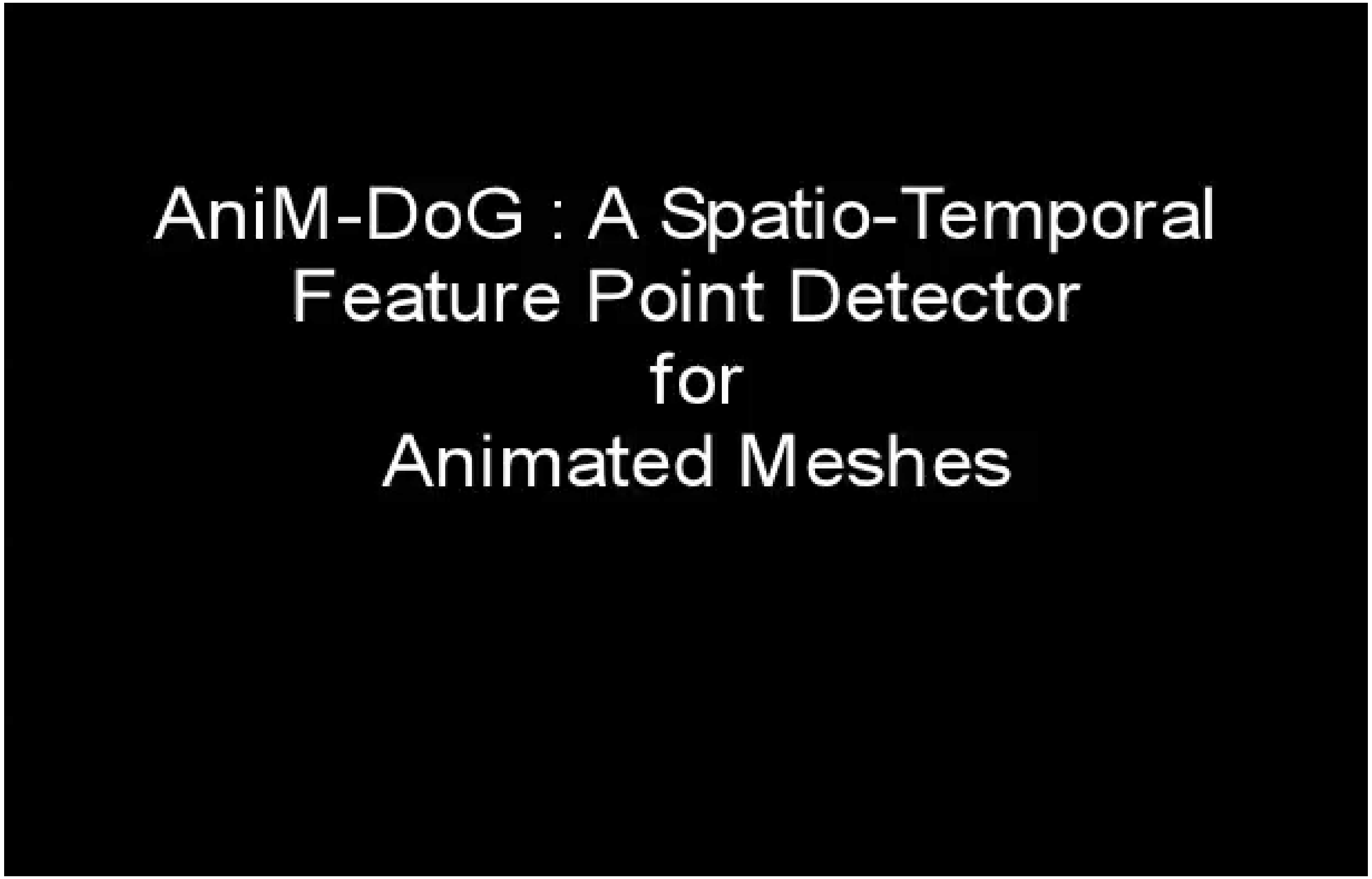
Results



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Conclusion

- New spatio-temporal scale representation of surface deformation
- Animation DoG filter
- Spatio-temporal animation features

Limitations/Future work

- Need more animation data sets

- **Descriptor**
- **Animation temporal alignment**
- **Animation matching**

mykhalchuk@unistra.fr