Global triangular mesh regularization using conditional Markov random fields

Vincent Vidal, Christian Wolf, Florent Dupont and Guillaume Lavoué

LIRIS UMR5205 CNRS/Université de Lyon/Université Lyon 1/INSA de Lyon

INSA de Lyon - Bâtiment Jules Verne, 20, av. Albert Einstein 69621 Villeurbanne cedex, France

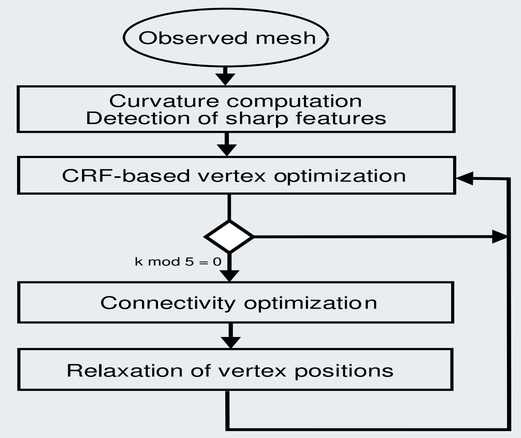
http://liris.cnrs.fr; Tel: +33 4 72 43 63 65; e-mail: vincent.vidal@liris.cnrs.fr

This work has been supported by French National Research Agency (ANR) through MDCO program (project MADRAS n˚ANR- ANR-07-MDCO-015)

Goals : remeshing with

- Better triangle quality
- Better vertex valence
- Preserved sharp features
- High fidelity to the initial surface

Remeshing pipeline



CRF-based vertex optimization : Gibbs energy minimization/probability maximization formulation

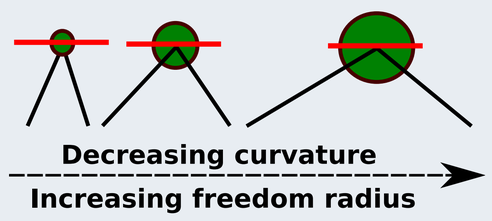
- Energy functional to minimize

$$U(x,y) = \sum_{r,s,t \in \mathcal{C}_3} \lambda_{shape}\psi_{shape}(x_r,x_s,x_t) + \sum_{s \in G} \lambda_{data}\psi_{data}(x_s,y) \quad (1)$$

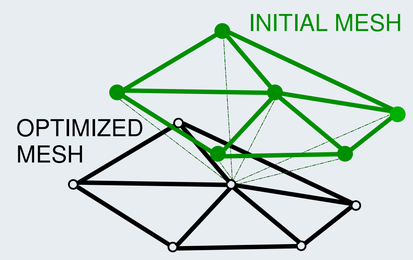
- $\psi_{shape}(x_r,x_s,x_t) = \frac{circumradius(x_r,x_s,x_t)}{min(||x_r-x_s||,||x_r-x_t||,||x_s-x_t||)}$
- $\psi_{data} = \frac{d}{d+|\varrho_{min}|}\tilde{x}_{s1}^2 + \frac{d}{d+|\varrho_{max}|}\tilde{x}_{s2}^2 + \tilde{x}_{s3}^2$

  (squared distance to the surface expressed in the closest observation Frenet frame)
- Minimize $U(x)$/maximize $P(x) = e^{-U(x)}$
- Complex continuous optimization problem
- Bayesian MAP estimation (inference)

- Candidate proposals
  - On the tangent plane
  - In a freedom sphere adapted to local curvature
  - Angle-based and Laplacian smoothing + guided random



- Global decision for each vertex (keep the new or the current position ?)
  - Global combination of local candidates
  - Kolmogorov et al.'s graph cut technique : st-graph representing the energy function+min cut/max flow to find out the configuration with minimal energy

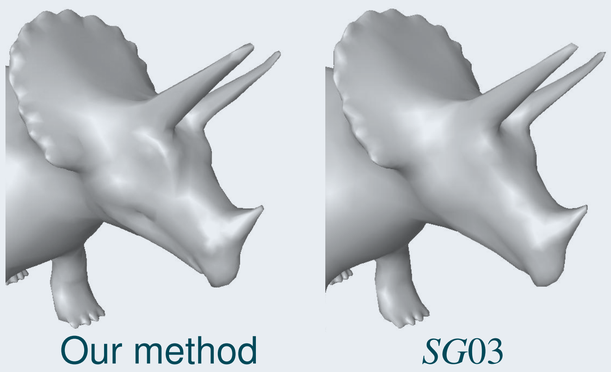


The initial mesh (input mesh) is used as the reference geometry for optimization purposes. The optimized/hidden mesh represents the dependency graph of the CRF. Each site node (optimized vertex) is possibly attached to all observed data.

Mesh connectivity optimization + vertex relaxation

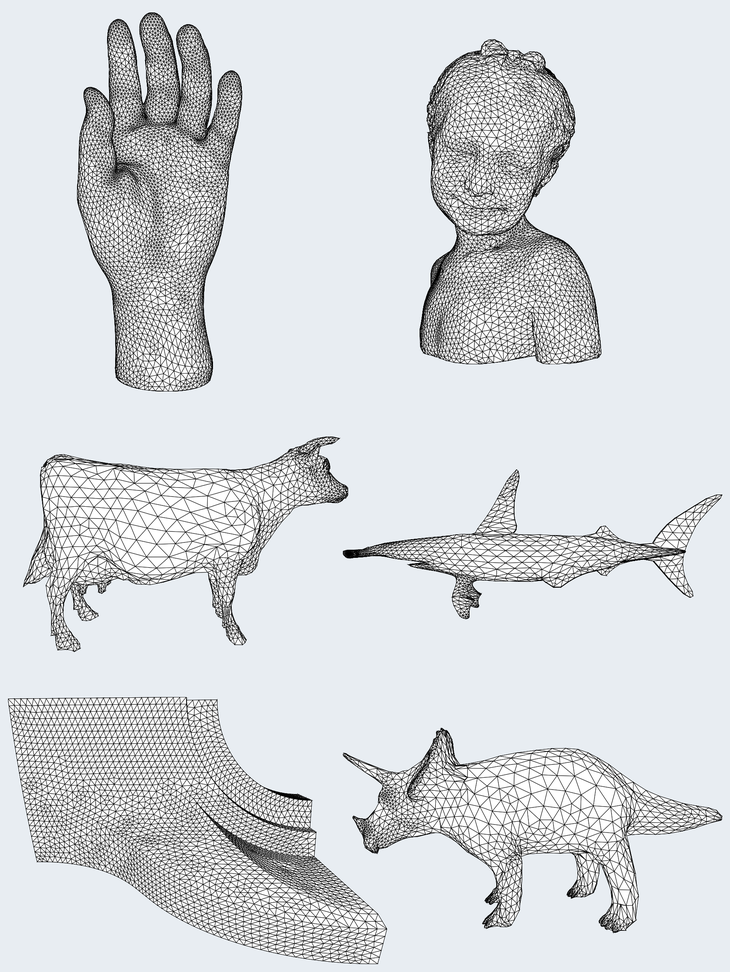
- Topological local operators
  - Edge-flip/split/collapse
  - Vertex split
  - Do them *smoothly* : priority queue on the shape improvement
- Vertex relaxation
  - Angle-based smoothing
  - Laplacian smoothing
  - Project them on the tangent plane
  - Let feature vertices unchanged

Comparison with SG03



Our method *SG*03

Remeshed models



Statistics on the remeshed models

Model	#v	Irreg (%)	Amin (deg)	Amax (deg)	Er_{Haus} (10^{-3})	Er_{RMS} (10^{-3})
Fandisk (init)	6495	20	43.4	86.1	-	-
Fandisk (Liu)	6495	20	44.7	82.0	3.3	0.8
Fandisk (our)	6361	**14**	**48.2**	**77.4**	**1.3**	**0.03**
Cow (init)	2892	53	30.8	92.4	-	-
Cow (Liu)	2892	53	35.1	88.2	5.3	0.9
Cow (our)	2743	**36**	**40.7**	**83.8**	**5.0**	**0.7**
Shark (init)	2560	31	20.8	97.4	-	-
Shark (Liu)	2560	31	26.2	107.5	**3.0**	**0.3**
Shark (Sur1)	2560	30	**50.6**	**71.1**	6.8	0.8
Shark (our)	2345	**23**	32.4	96.3	3.8	**0.3**
Hand (init)	7950	58	32.3	94.1	-	-
Hand (Liu)	7950	58	34.3	92.2	8.8	0.4
Hand (Val)	6802	45	46.1	77.5	2.6	**0.2**
Hand (our)	6800	**28**	**48.1**	**76.5**	**2.0**	**0.2**
Bimba (init)	8857	62	34.2	92.7	-	-
Bimba (Liu)	8857	62	38.1	87.0	4.9	0.5
Bimba (Sur1)	8857	**20**	**53.6**	**67.6**	6.0	0.5
Bimba (Val)	8143	48	45.2	78.1	6.0	0.4
Bimba (our)	8143	37	46.9	77.0	**3.4**	**0.2**
Triceratops (init)	2832	59	29.6	95.5	-	-
Triceratops (Sur2)	2758	**13**	**42.2**	**82.5**	8.4	1.1
Triceratops (our)	2693	37	41.0	83.9	**3.9**	**0.5**

Liu, Val, Sur1 and Sur2 correspond respectively to *LTJW*07, *VCP*08, *SAG*03 and *SG*03.

Conclusions

- We have presented a CRF-based vertex repositioning for solving a complex continuous optimization problem using discrete optimization techniques.
- The presented results show a good triangle shape quality while maintaining a high surface fidelity.