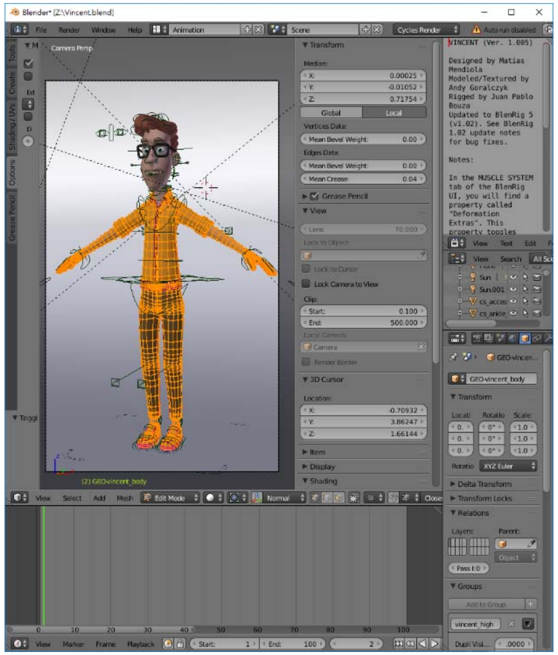
Interactive Modeling and Animation – From 2D to 3D

Speaker: Ph.D. Chih-Kuo Yeh (葉智國)

成功大學

Computer Graphics Group/Visual System Lab

Computer graphics

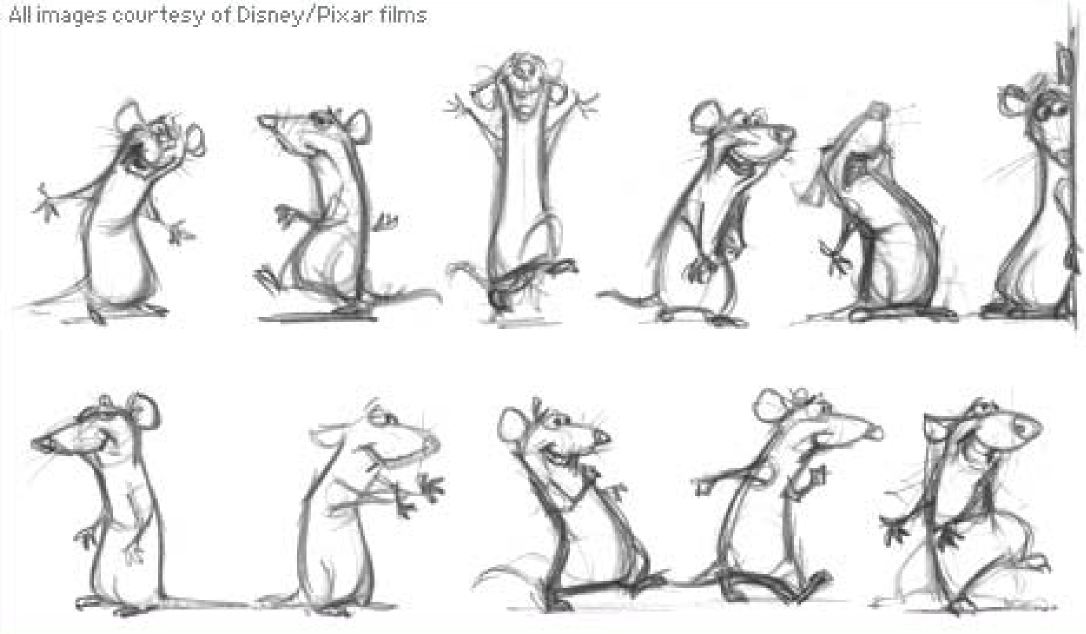


Modeling

Animation

Rendering

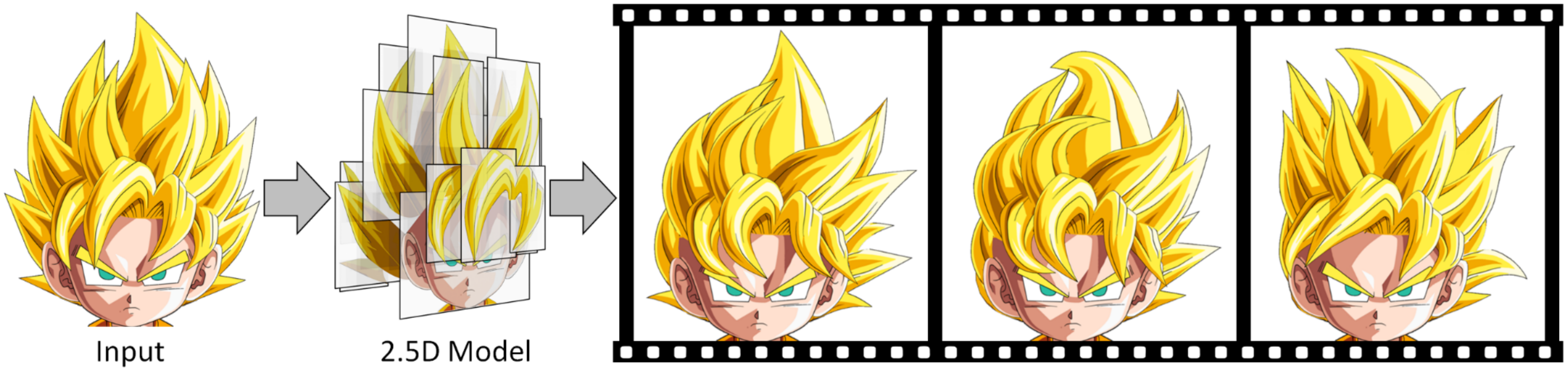
All images courtesy of Disney/Pixar films



Celluloid Animation

2.5D Cartoon Hair Modeling and Manipulation

2.5D Cartoon Hair Modeling



Chih-Kuo Yeh, Pradeep Kumar Jayaraman, Xiaopei Liu, Chi-Wing Fu and Tong-Yee Lee, "2.5D Cartoon Hair Modeling and Manipulation." IEEE Transactions on Visualization and Computer Graphics, vol. 21, no. 3, pp. 304–314, 2015. (SCI)

Related Work

[Sugisaki 2005]

[Chai 2012 Siggraph]

Overview

(a) input (b) segmentatic

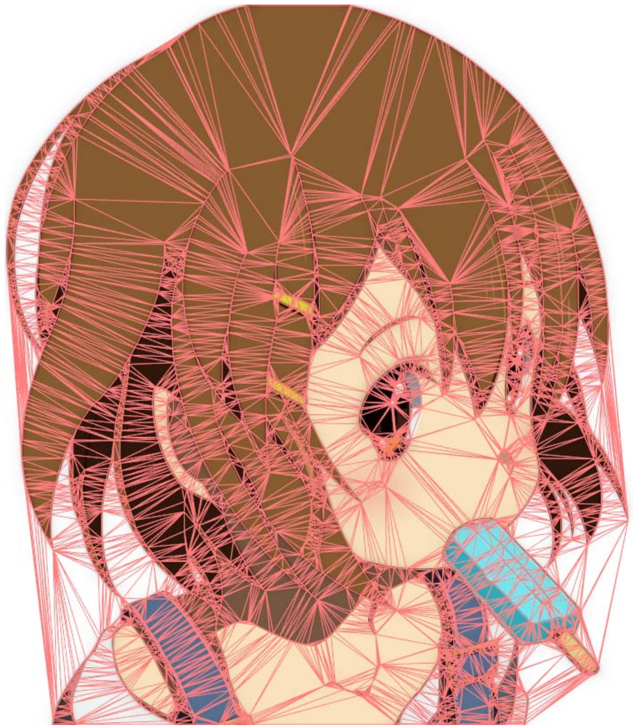
Input cartoon image

Curve Extraction

- By using M.-M. Cheng. Curve structure extraction for cartoon images. In Harmonious Human Machine Env., pages 13-25, 2009.
- Smooth and simplify the curves.

Delaunay Triangulation

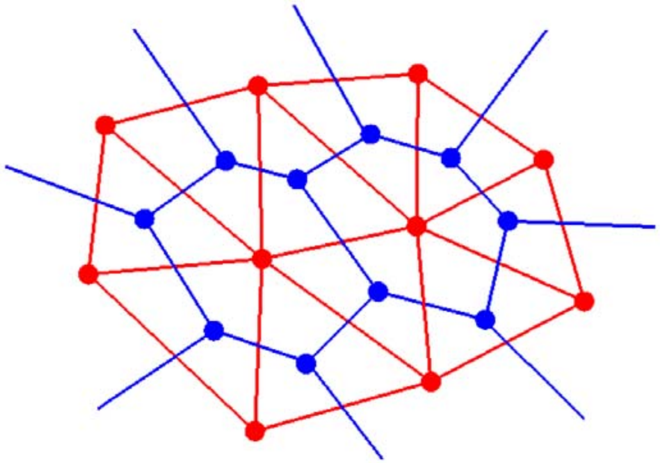
- Delaunay Triangulation is used to partition the image



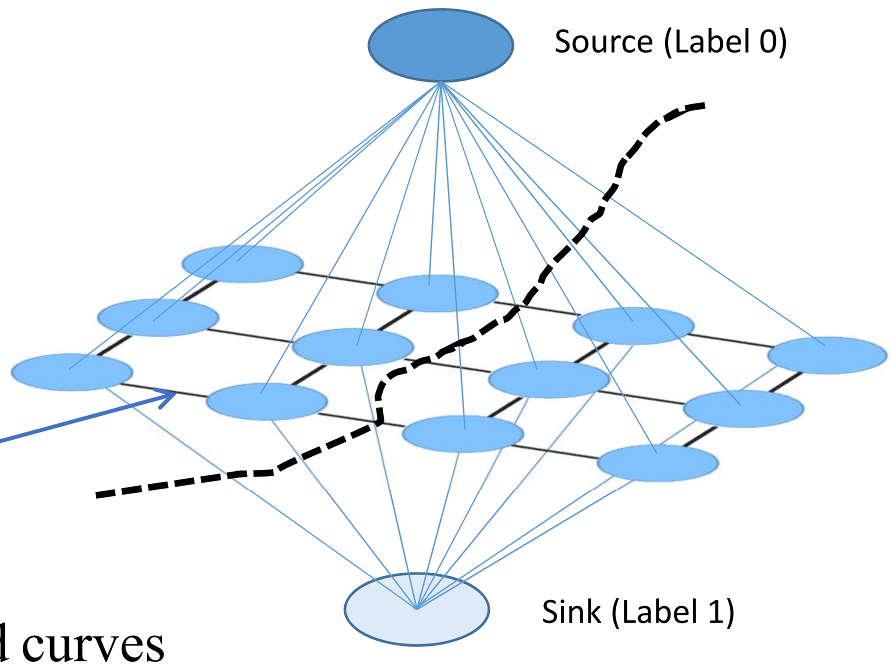
Graph Cut From Dual Graph

- Markups for segmenting hair strands

Graph Cut From Dual Graph



Red color : triangle mesh
Blue color : dual graph



Cost to split nodes

$$w(e_{ij}) = \varphi_{ij} \| e_{ij} \|$$

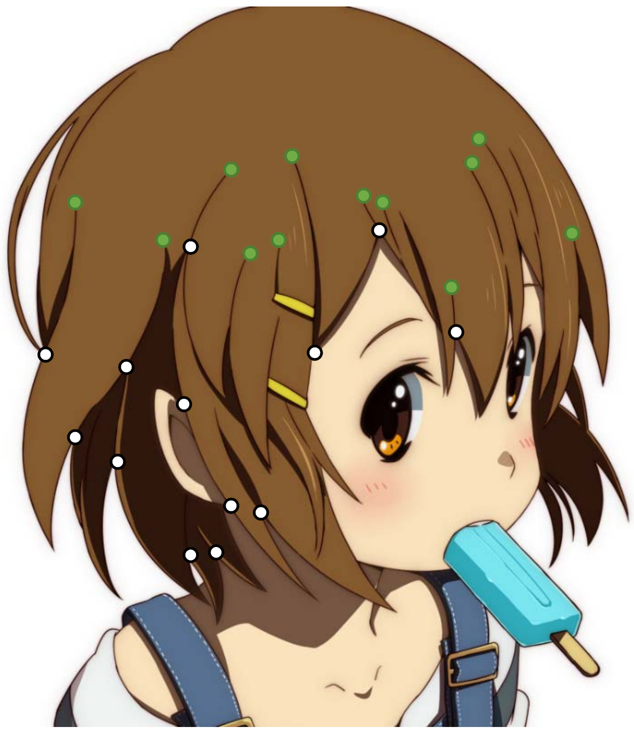
$$\varphi_{ij} = \begin{cases} 0, \text{if extracted curves} \\ 30, \text{otherwise} \end{cases}$$

Segmentation

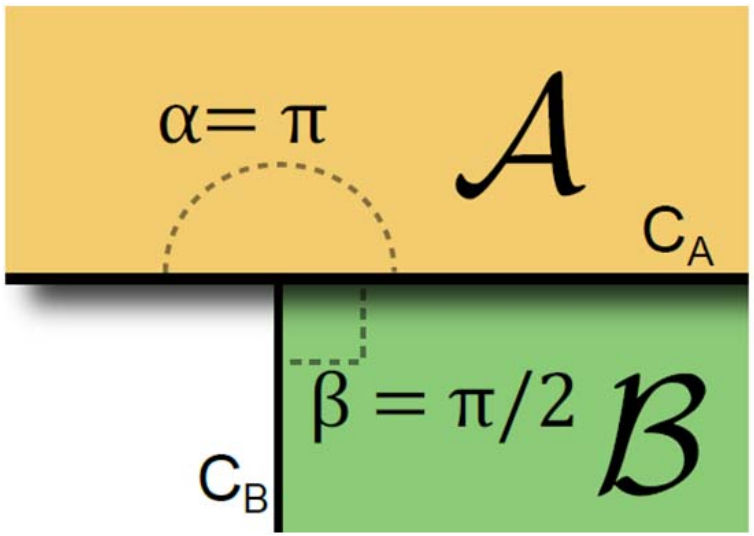
Cartoon Hair Layering

Junctions and Cusp Points

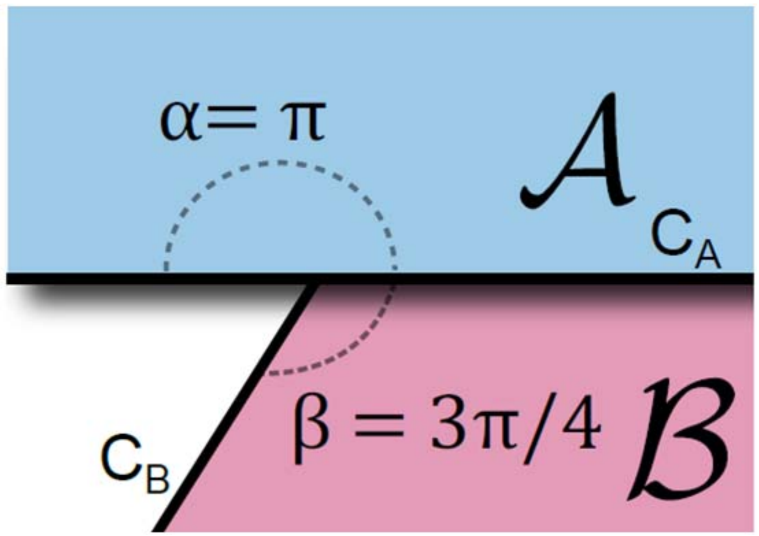
- Cusp point
- Junction



Junction

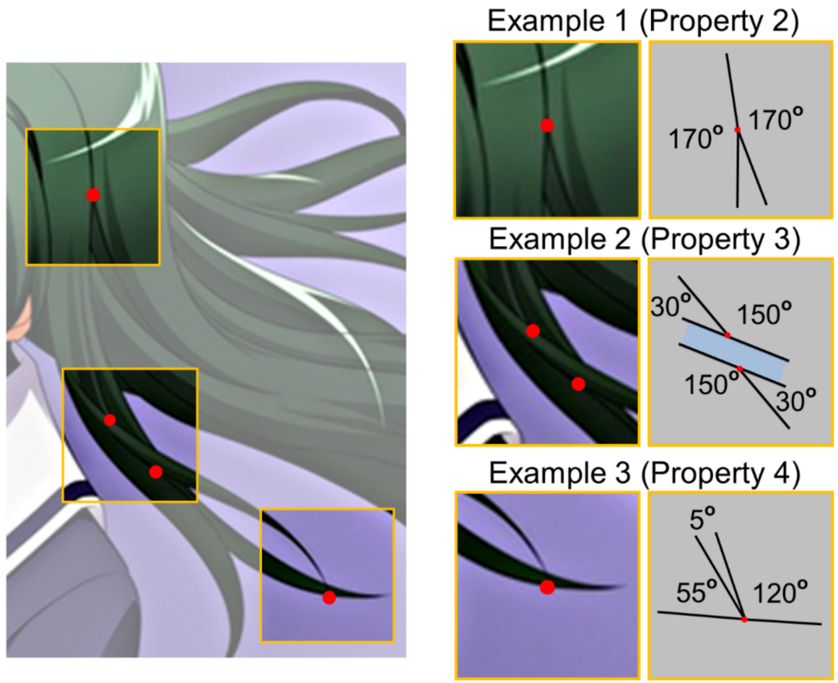


α= π
$\mathcal{A}$
C_A
β = π/2
$\mathcal{B}$
C_B

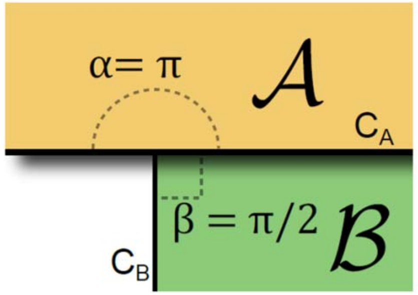


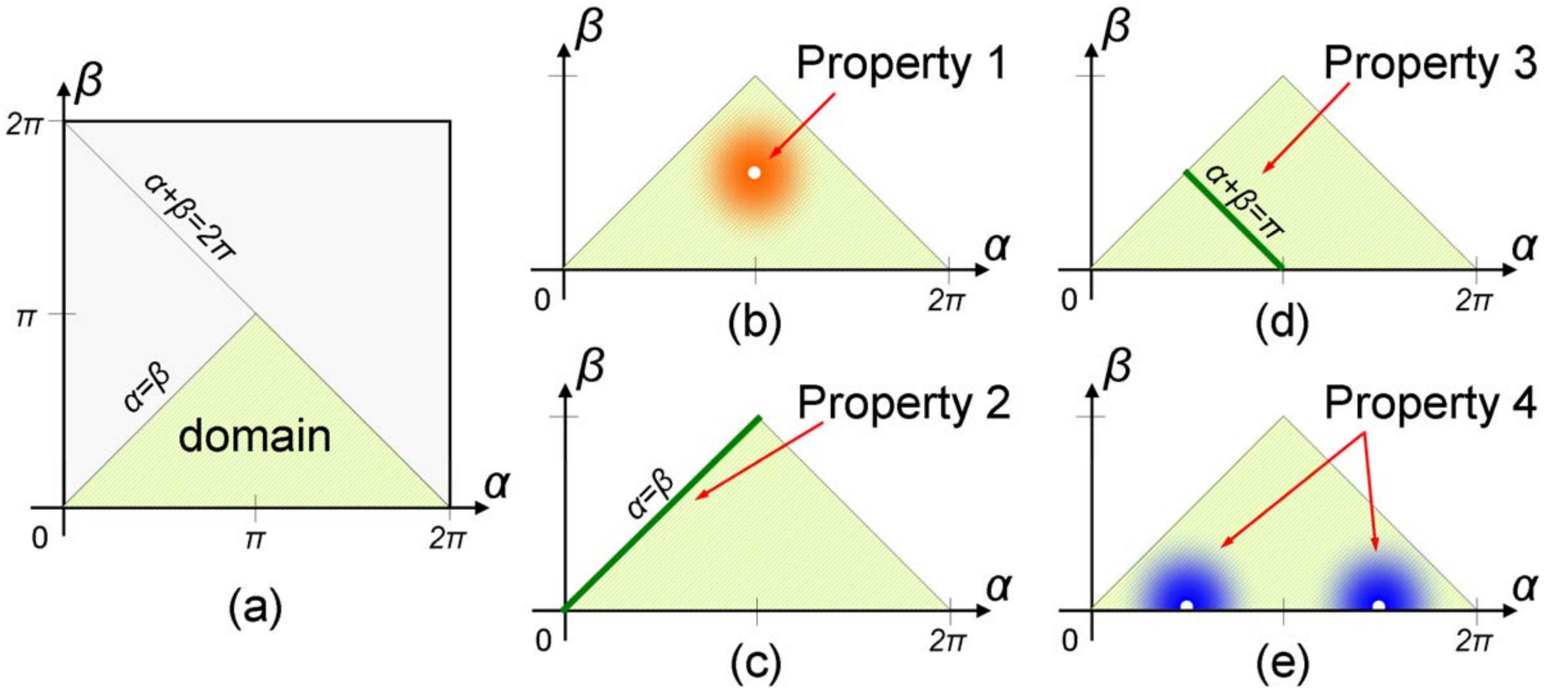
α= π
$\mathcal{A}$
C_A
β = 3π/4
$\mathcal{B}$
C_B

Example Cartoon Hairs

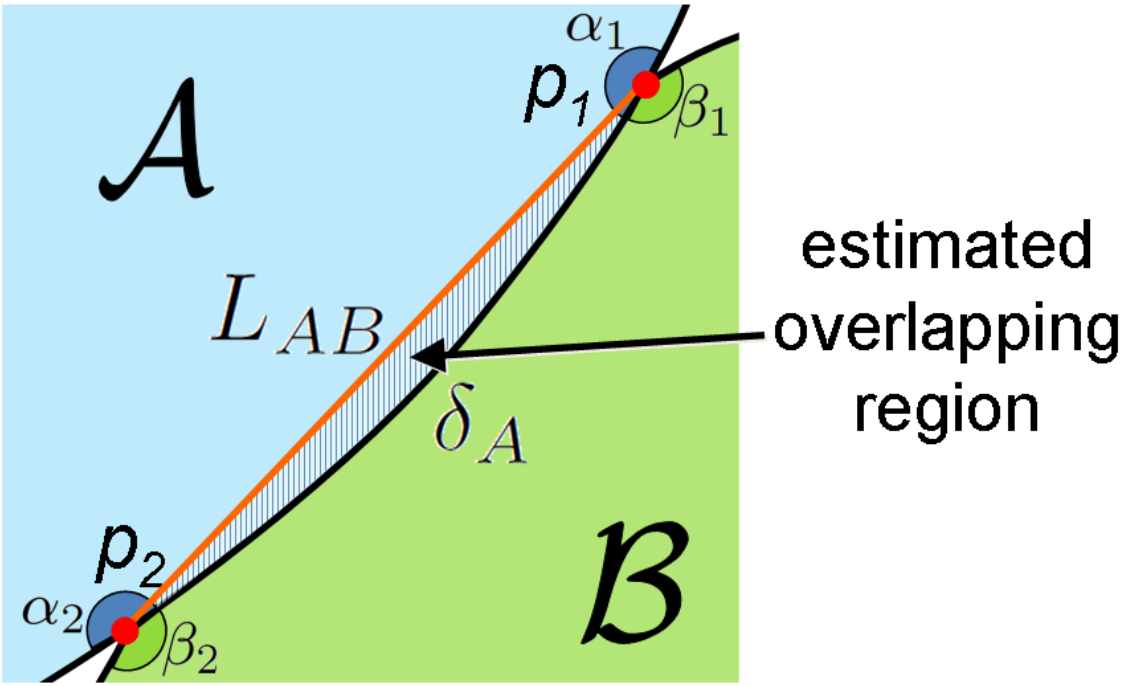


Properties of the junction metric



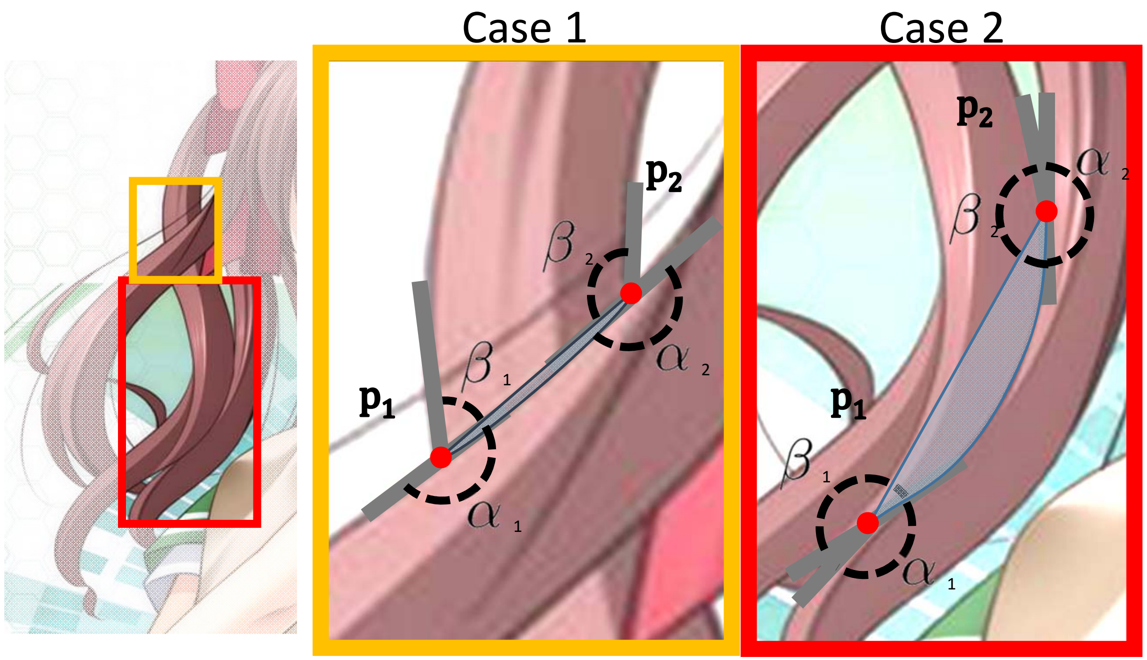


The Region Overlap Metric



$$\Phi_R(A,B) = \delta_A - \delta_B$$

Extreme case study



$\hat{\Phi}_J$ works but not Φ_R Φ_R works but not $\hat{\Phi}_J$

Local layering metric

$$\Phi(A,B) = \hat{\Phi}_J(A,B) + \Phi_R(A,B)/|L_{AB}|^2$$

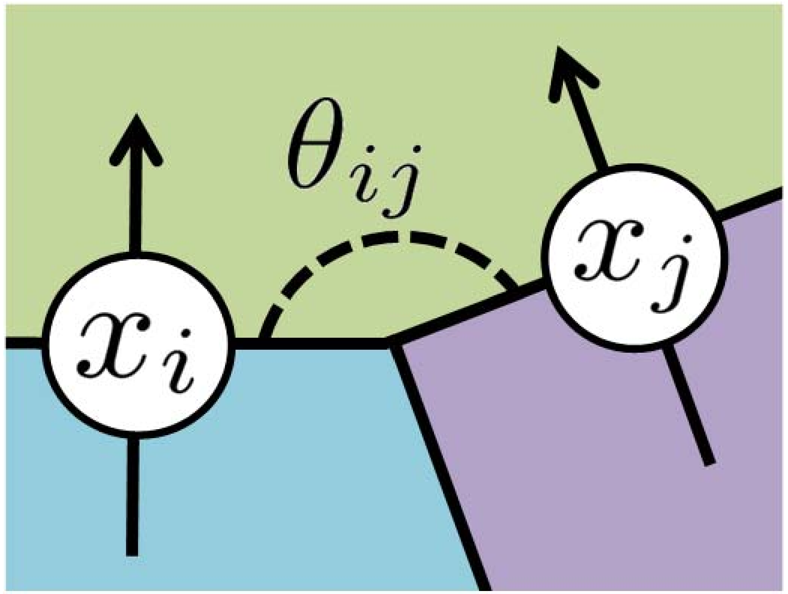
$$\hat{\Phi}_J(A,B) = s(p_1)\Phi_J(\alpha_1,\beta_1) + s(p_2)\Phi_J(\alpha_2,\beta_2)$$

$$\Phi(A,B) > 0 : \mathrm{A} \leftarrow \mathrm{B}$$
$$\Phi(A,B) < 0 : \mathrm{A} \rightarrow \mathrm{B}$$
$$\Phi(A,B) = 0 : \mathrm{A} \leftrightarrow \mathrm{B}$$

Layering Optimization

$$\underset{\{x_i\}}{\operatorname{argmin}}\left\{-\sum_{i\in V'}\Phi(v_i)x_i - \sum_{e_{ij}\in E'}\phi_{ij}x_ix_j\right\}$$

$$\phi_{ij} = \tan\left(\left|\left(\theta_{ij} \bmod \pi\right) - \pi/2\right|\right)$$

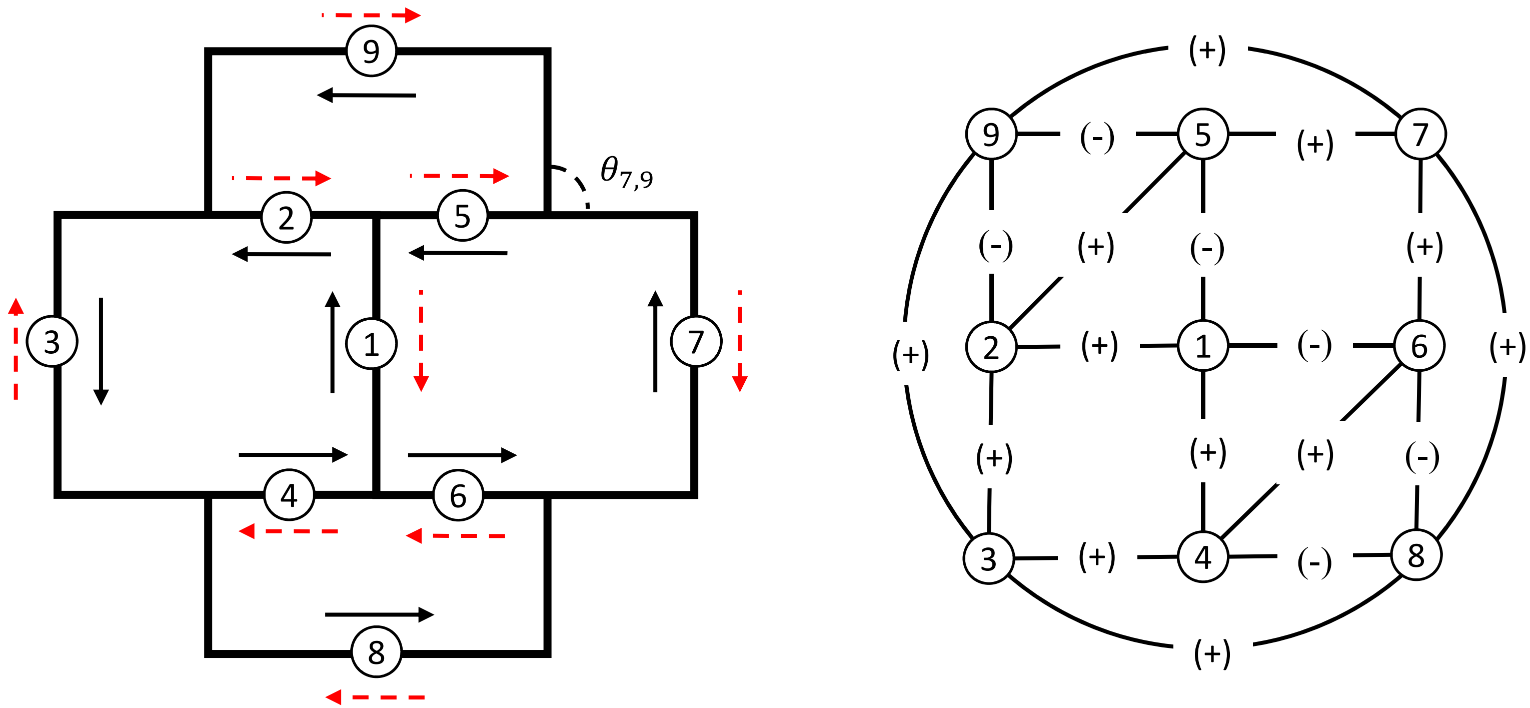


Junction metric for layering

- If α is close to π and β is close to $\pi / 2$, we regard $\boldsymbol{A}$ as on top of $\boldsymbol{B}$, i.e., $\boldsymbol{B} \rightarrow \boldsymbol{A}$.
- If $\alpha \approx \beta$, the junction metric should not suggest any ordering preference, i.e., $\boldsymbol{A} \leftrightarrow \boldsymbol{B}$.
- If $\alpha + \beta \approx \pi$, the junction metric should not suggest any ordering preference, i.e., $\boldsymbol{A} \leftrightarrow \boldsymbol{B}$
- If β is close to 0 while α is not close to 0 and π, we regard $\boldsymbol{B}$ as on top of $\boldsymbol{A}$, i.e., $\boldsymbol{A} \rightarrow \boldsymbol{B}$

$$\Phi_J(\alpha, \beta) = \left|(\alpha \bmod \pi) - \frac{\pi}{2}\right| - \left|(\beta \bmod \pi) - \frac{\pi}{2}\right|$$

$$\underset{\{x_i\}}{\operatorname{argmin}}\left\{-\sum_{i\in V'}\Phi(v_i)x_i-\sum_{e_{ij}\in E'}\delta_{ij}\phi_{ij}x_ix_j\right\}\qquad \phi_{ij}=\tan\left(\left|\left(\theta_{ij}\bmod\pi\right)-\pi/2\right|\right)$$



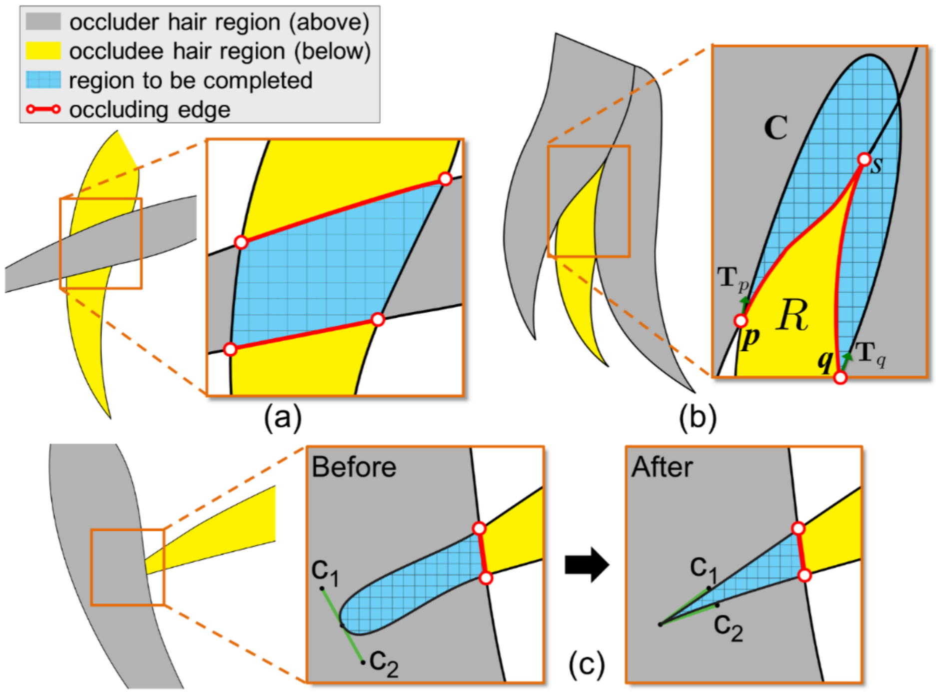
Cartoon Hair Completion

Input

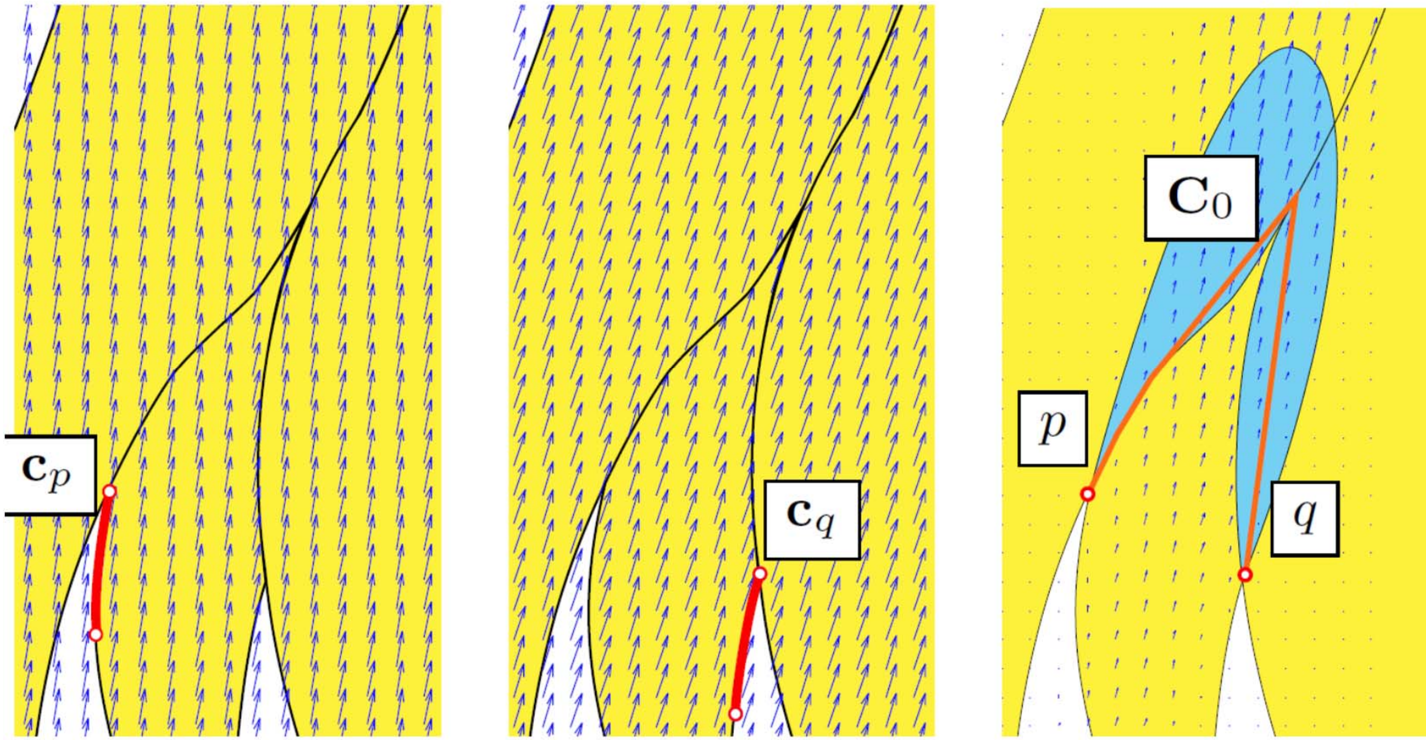
Without completion

With completion

Cartoon Hair Completion



Vector fields



Hamiltonian function

$$H_p(x) = \frac{1}{2} x^T A_p x + x^T B_p$$

$$\begin{cases} \dot{C}_p(t) = \left(\frac{\partial H_p(C_p(t))}{\partial y}, -\frac{\partial H_p(C_p(t))}{\partial x} \right) \\ \frac{\partial H_p(C_p(s))}{\partial t} = 0 \end{cases}$$

External force field

$$F_p(x) = R(-\pi/2)\nabla H_p = R(-\pi/2)(A_p x + B_p)$$

$$F_{ext}(x) = \Omega(x)\left(tF_p(x) + (1-t)F_q(x)\right)$$

$$\Omega(x) = Sigmoid\left(\Gamma_p(x) \cdot \Gamma_p(x)\right)$$

$$\Gamma_p(x) = \max\left(H_p(p) - H_p(x), 0\right)$$

$$\Gamma_q(x) = \max\left(H_q(x) - H_q(q), 0\right)$$

Iterative Refine Algorithm

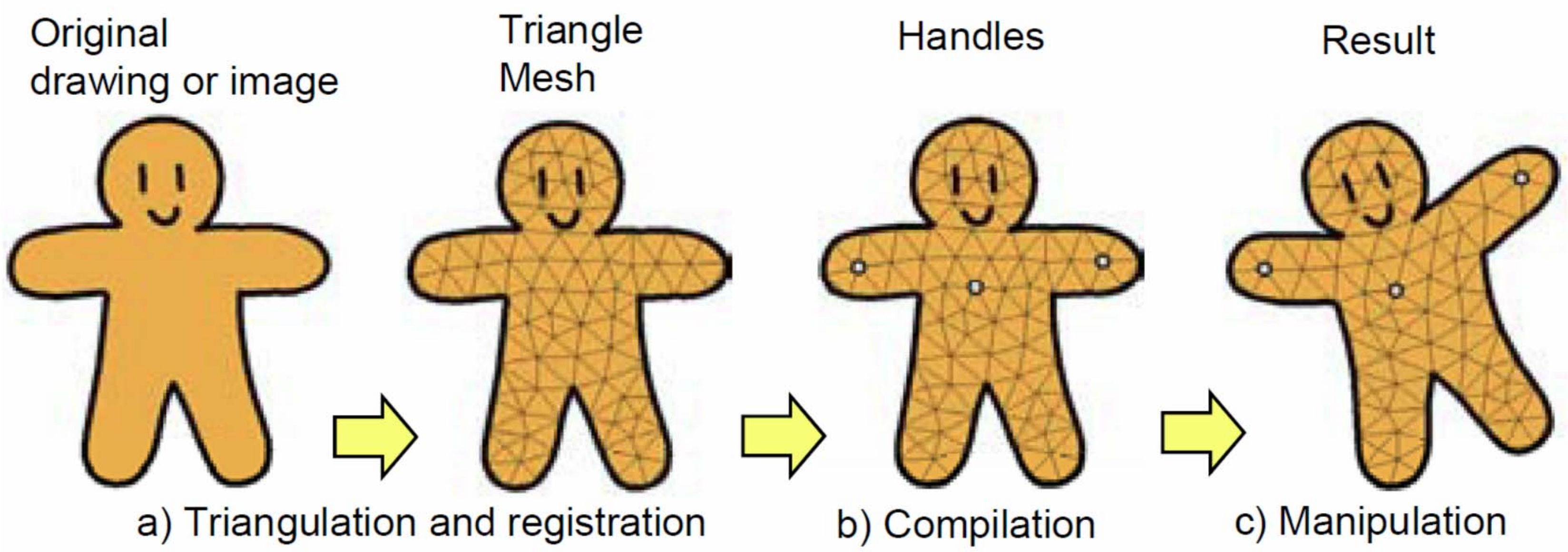
Algorithm 1 ITERATIVE_REFINE $(\mathbf{C}_0, F_{ext})$

$i \Leftarrow 0$
while true do
  $i \Leftarrow i + 1$
  for each sample point $\mathbf{C}_{i-1}(t)$ **do**
    $V_i(t) \Leftarrow ||F_{ext}(\mathbf{C}_{i-1}(t)) \cdot N(\mathbf{C}_{i-1}(t))||N(\mathbf{C}_{i-1}(t))$
    $\mathbf{C}_i(t) \Leftarrow (I - \mathbb{A})^{-1}[\mathbf{C}_{i-1}(t) + V_i(t)]$
    if $\mathbf{C}_i(t)$ outside $O(R)$ **then**
      return $\mathbf{C}_{i-1}$
    end if
  end for
  if $||V_i|| < \epsilon$ **then**
    return $\mathbf{C}_i$
  end if
end while

Cartoon Hair Animation and Manipulation

Hair Editing

As-Rigid-As-Possible Shape Manipulation



Hair Editing

$$\Omega = w_R \Omega_R + w_H \Omega_H + w_C \Omega_C$$

$$\Omega_R = \sum_{i \in V, k \in S} w_i^k \left\| (v_i - s_k) - T_k (v_i' - s_k') \right\|^2$$

$$T_k = R_{(1,0)}^{e_k'} \begin{bmatrix} s & 0 \\ 0 & 1 \end{bmatrix} R_{e_k}^{(1,0)}$$

$$\Omega_H = \sum_{(i,j) \in E} w_{ij} \left\| v_j' - v_i' \right\|^2$$

$$w_{ij} = \cot \alpha_{ij} + \cot \beta_{ij}$$

$$\Omega_C = \sum_{i \in C} \left\| v_i - v_i' \right\|^2$$

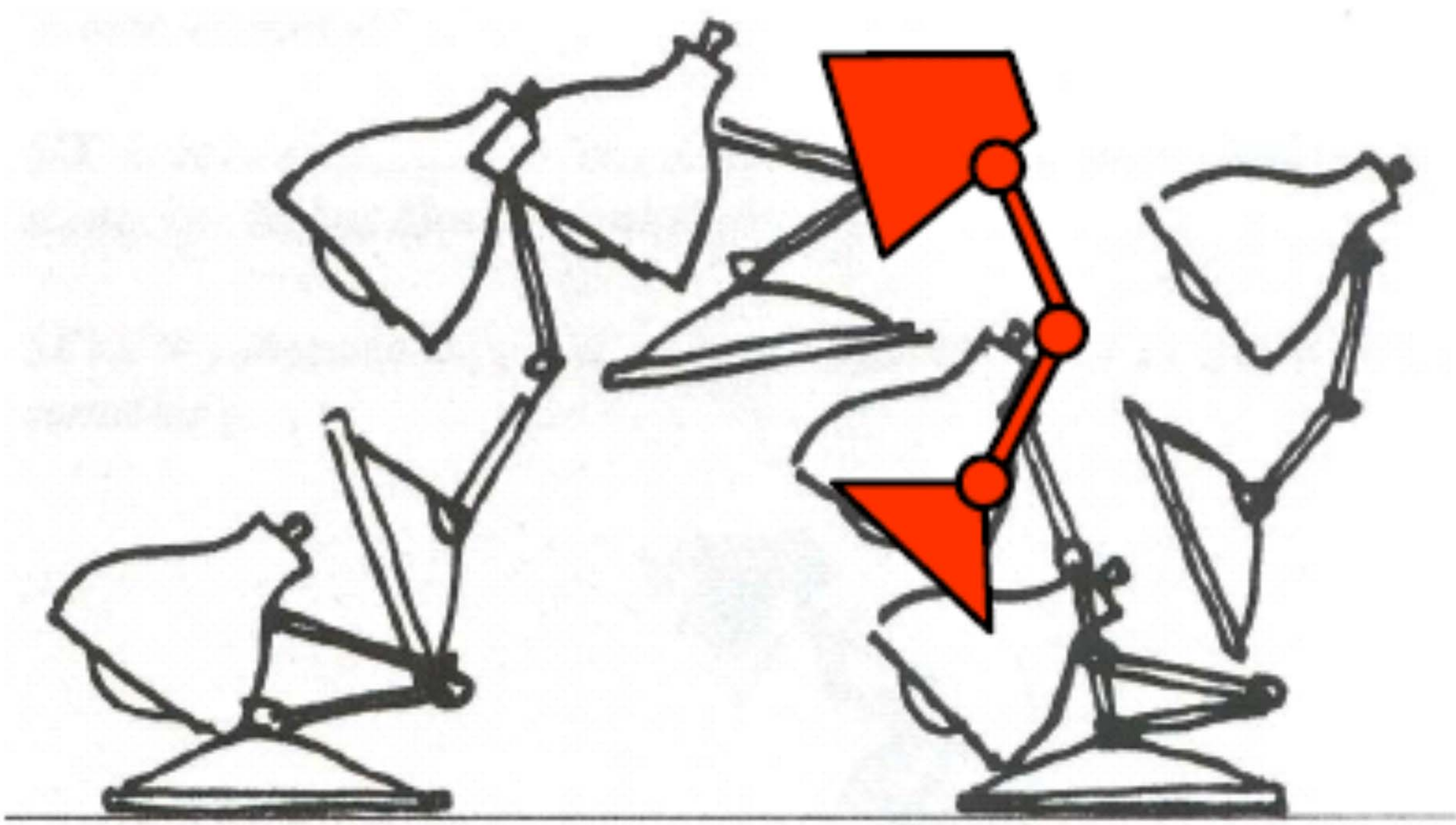
1. Deformation term
2. Smoothness term
3. Constraint term

Hair Braiding

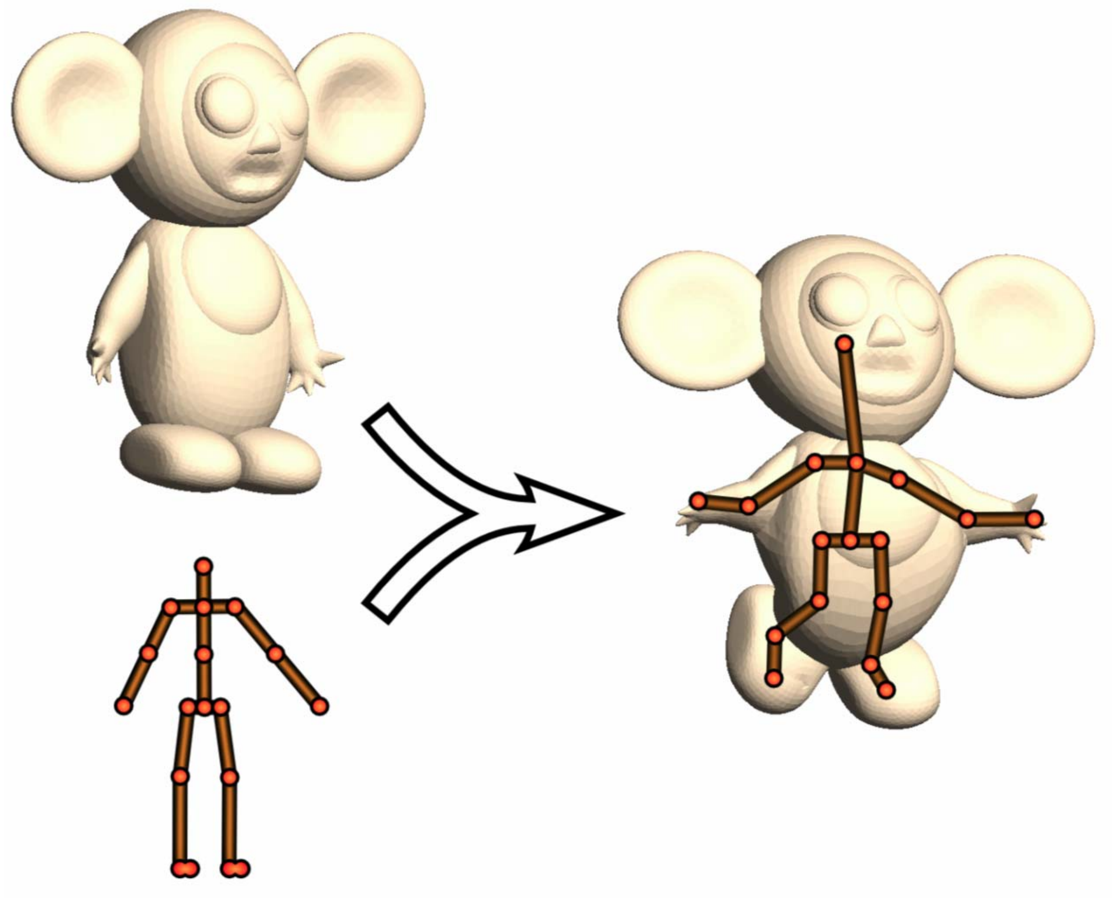


Animation

Keyframe & Inbetweening



Skeletal Animation



Cartoon Hair Animation

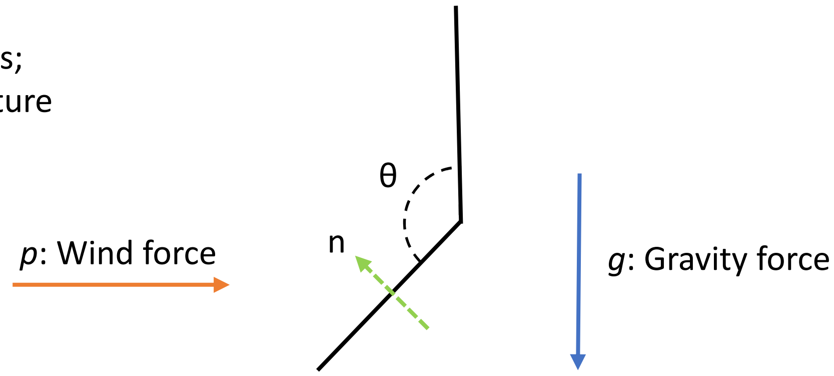
Bending force $f = \gamma \kappa n$

γ is the stiffness;
κ is local curvature

Total force $F = -pn + f + g$

$$\ddot{\theta} = \alpha F \cdot n$$

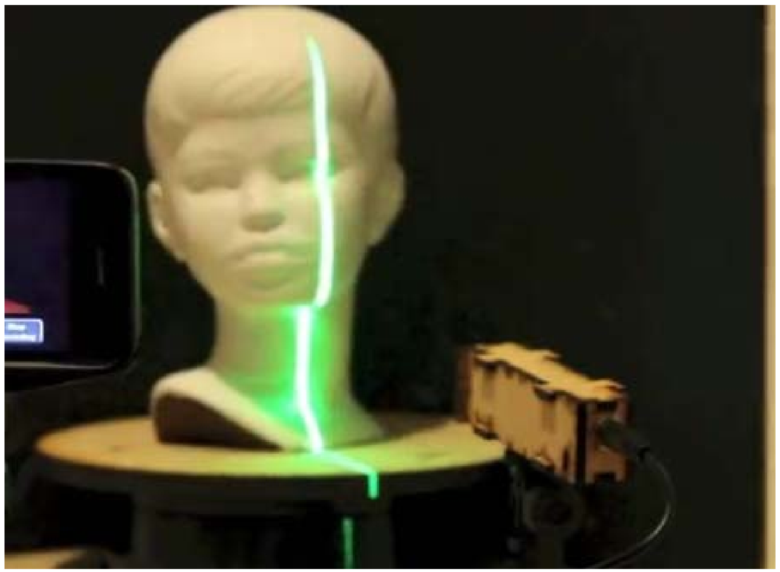
$$\alpha = \alpha_0 d^{\lambda}$$

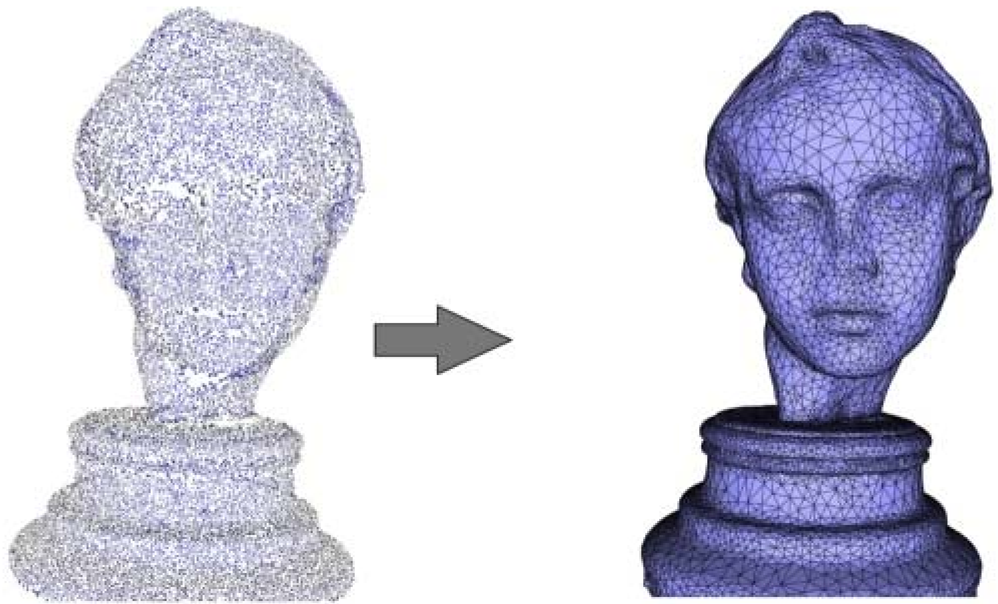


α_0 is the base rotation rate;
d is the distance from the hair root along the skeleton;
λ is the user-controllable parameter for tuning the amount of hair bending.
p used Lattice Boltzmann model to solve the incompressible Navier-Stokes equation.

3D Reconstruction

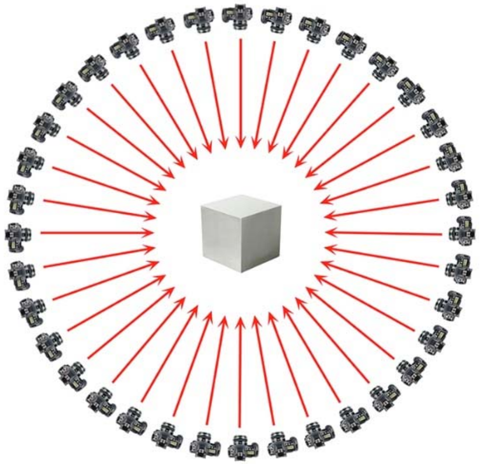
3D Laser Scanner

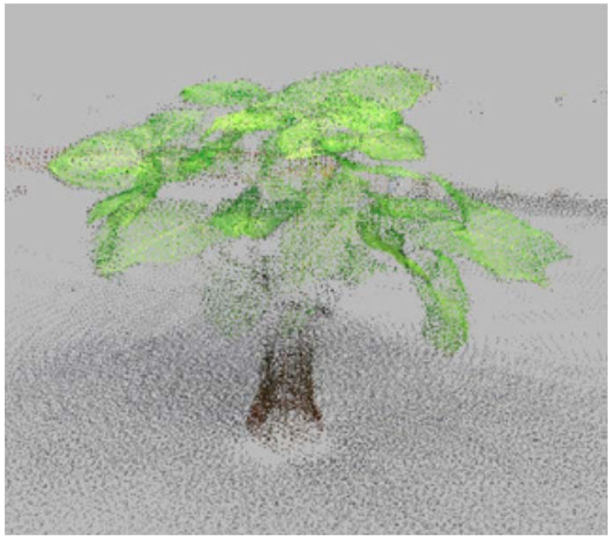




Poisson Surface Reconstruction

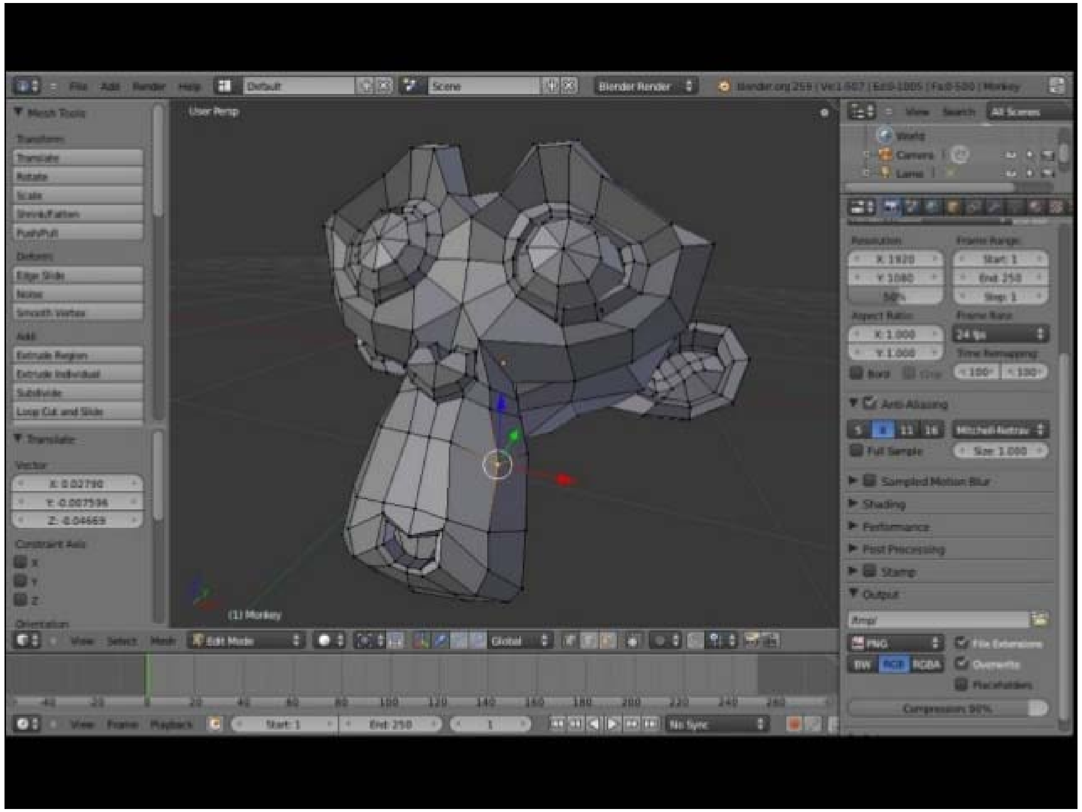
Structure from Motion





Interactive 3D Modeling

- Polygonal modeling
- Curve modeling
- Digital sculpting

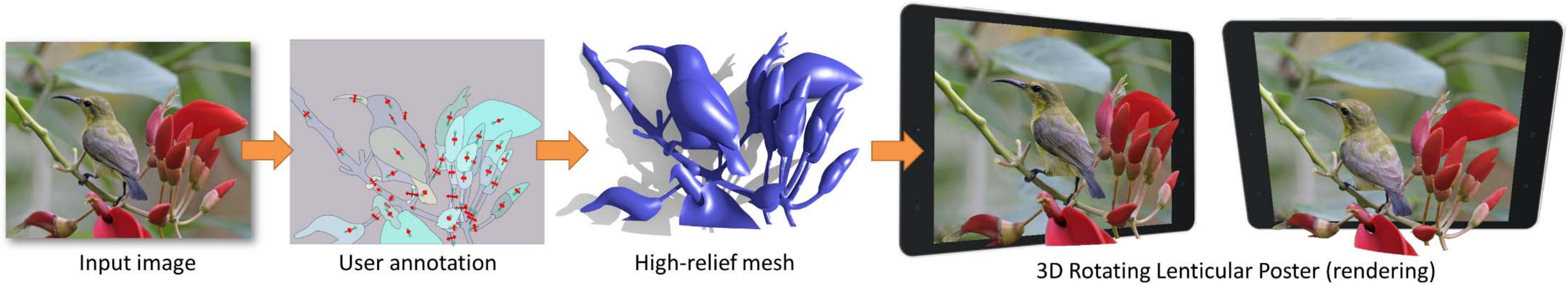


Workload of Artist

Blood Frontier

- GUI or menu graphics 4 - 8 hours
- One level texture 1 - 2 hours
- One scenery object 4 - 8 hours
- One detailed object(animated or seen up close, like a gun) 8 - 12 hours
- One good room in a map 2 - 4 hours
- **Modeling and painting a character 30 - 50 hours**
- Rigging a character 4 - 8 hours
- Animating a character, per short animation 1 - 2 hours

Introduction



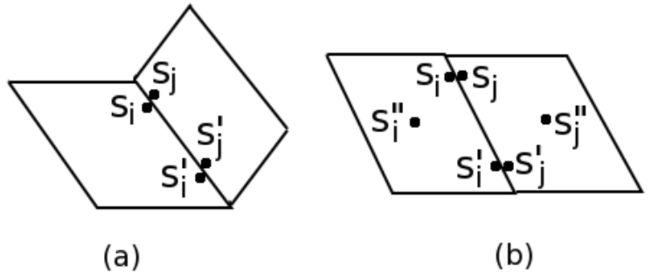
Chih-Kuo Yeh, Shi-Yang Huang, Pradeep Kumar Jayaraman, Chi-Wing Fu and Tong-Yee Lee, “Interactive High-Relief Reconstruction for Organic and Double-sided Objects from a Photo.” IEEE Transactions on Visualization and Computer Graphics, vol. 23, no. 7, pp. 1796-1808, July 1 2017. (SCI)

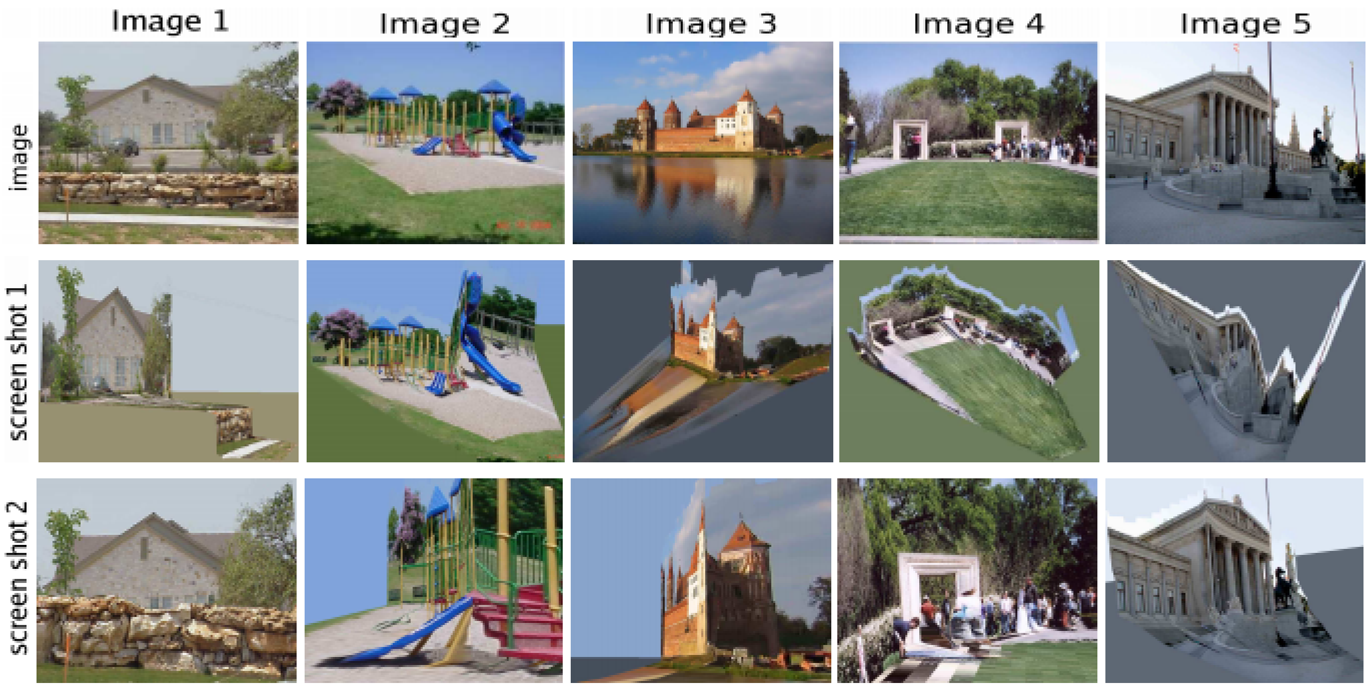
Interactive 3D Reconstruction

- Just input single image
- Folded structures
- Double-sided structures
- Manual effort is quite little
- Handle complex organic objects with multiple occluded regions and varying shape profiles
- Generate high-relief geometry with large viewing angles

Related Work

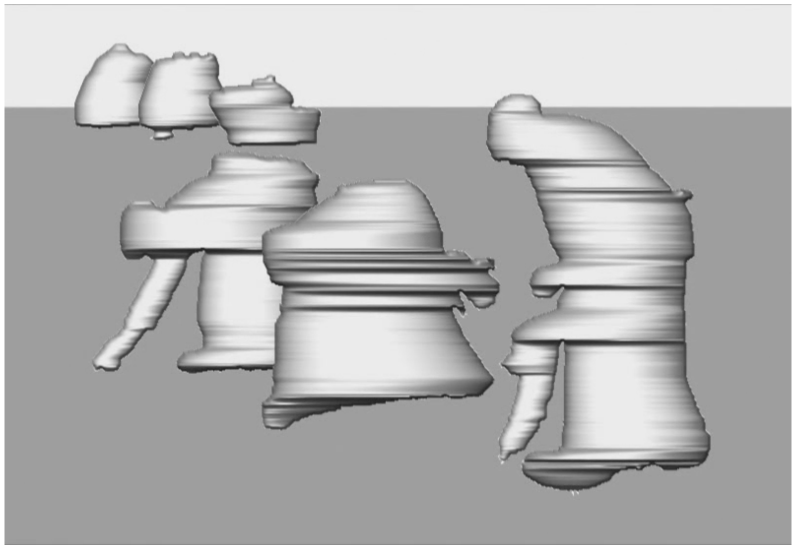
- Single-view 3D Reconstruction
  - **Fully automatic**
  - 2008 - Make3D: Learning 3D Scene Structure from a Single Still Image





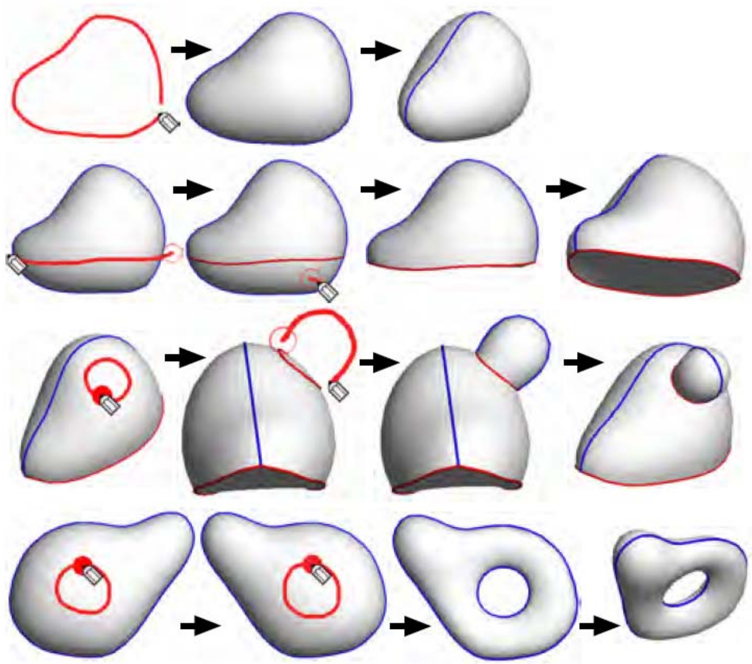
Related Work

- Single-view 3D Reconstruction
  - **Fully automatic**
    - 2015 - Hallucinating-stereoscopy-single-image

Related Work

- Single-view 3D Reconstruction
  - **User-driven**
    - 2007 - FiberMesh: Designing Freeform Surfaces with 3D Curves



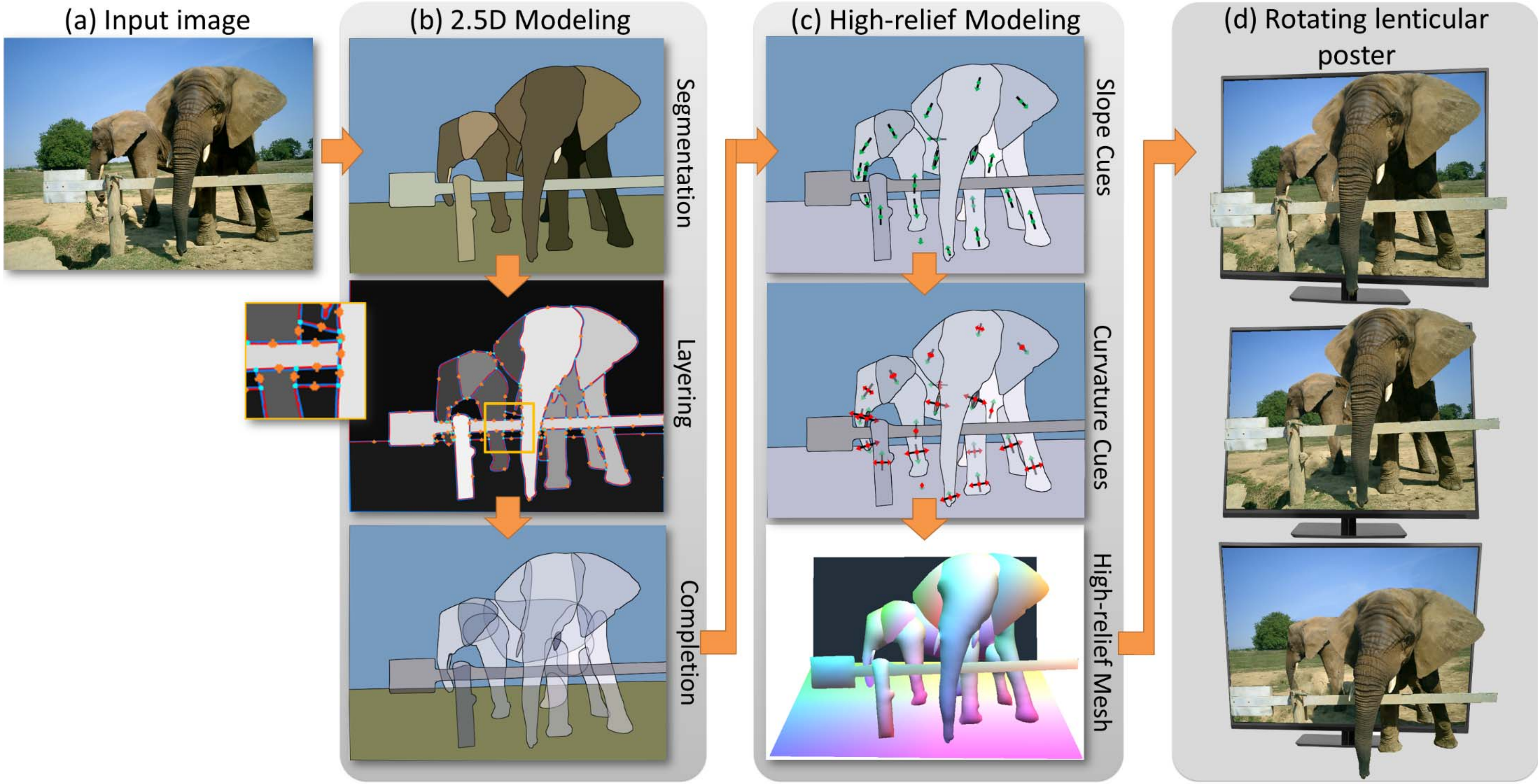
Related Work

- Single-view 3D Reconstruction
  - **User-driven**
    - 2013 - 3-Sweep Extracting Editable Objects from a Single Photo

Related Work

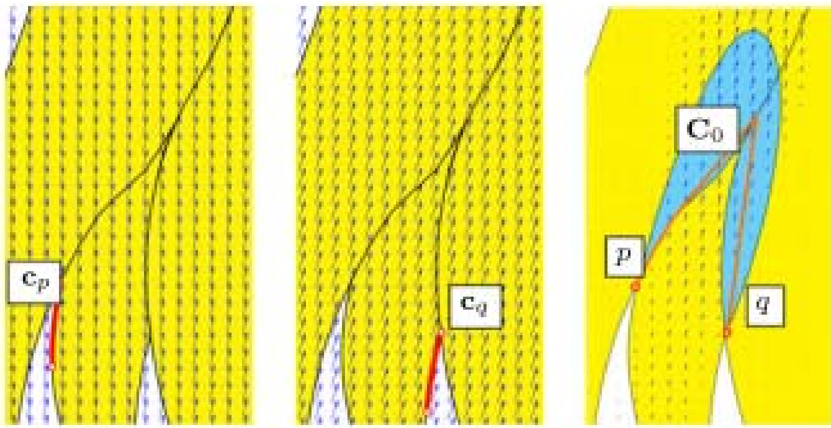
- Single-view 3D Reconstruction
  - **Semi-automatic**
    - 2014 - Ink-and-Ray Bas-Relief Meshes for Adding Global Illumination Effects to Hand-Drawn Characters

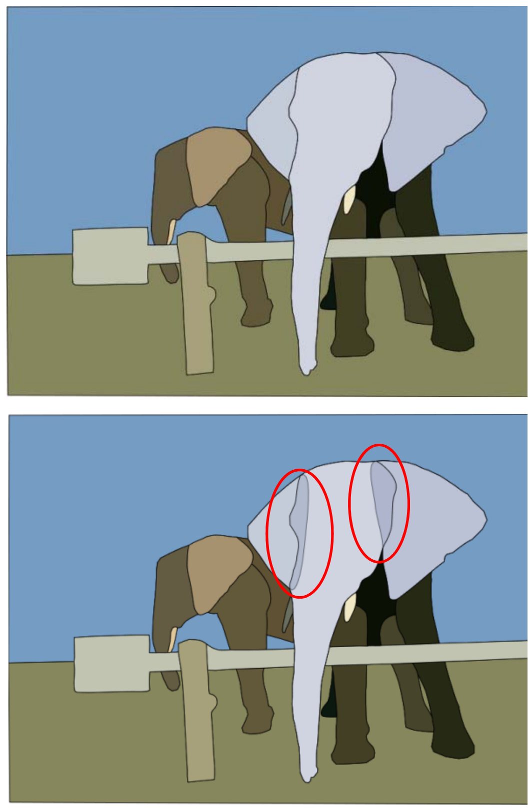
System Overview



Completion

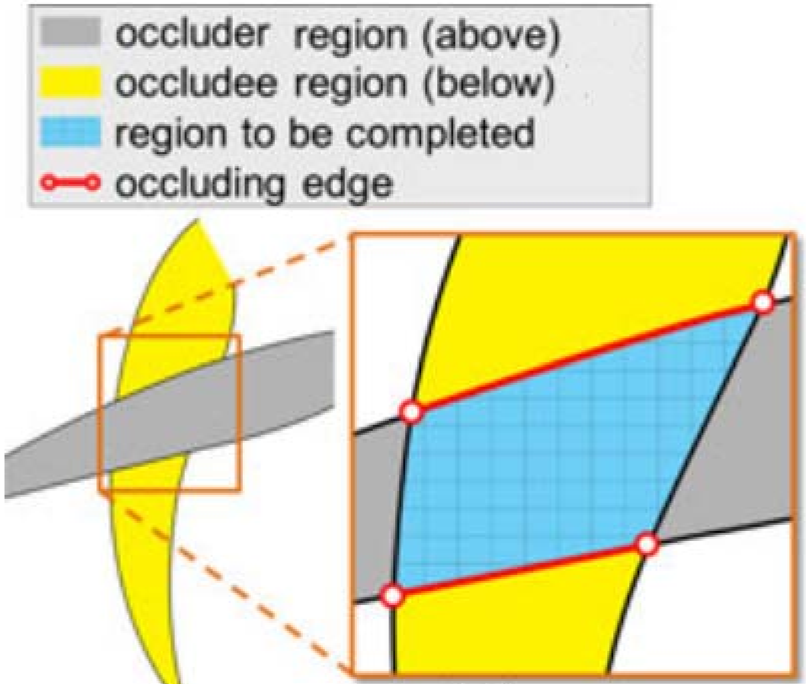
- Case (i): Expand a single region from the occluding boundary



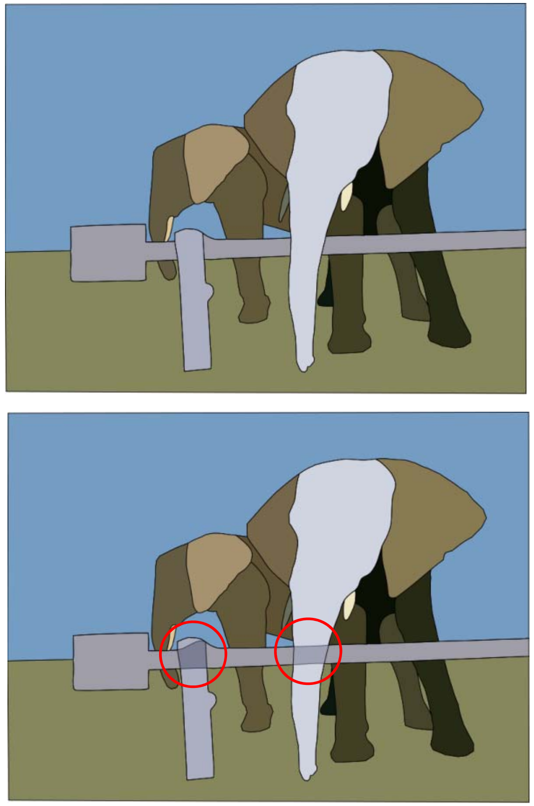


Completion

- Case (ii): Connect non-neighboring regions under a common occlusion



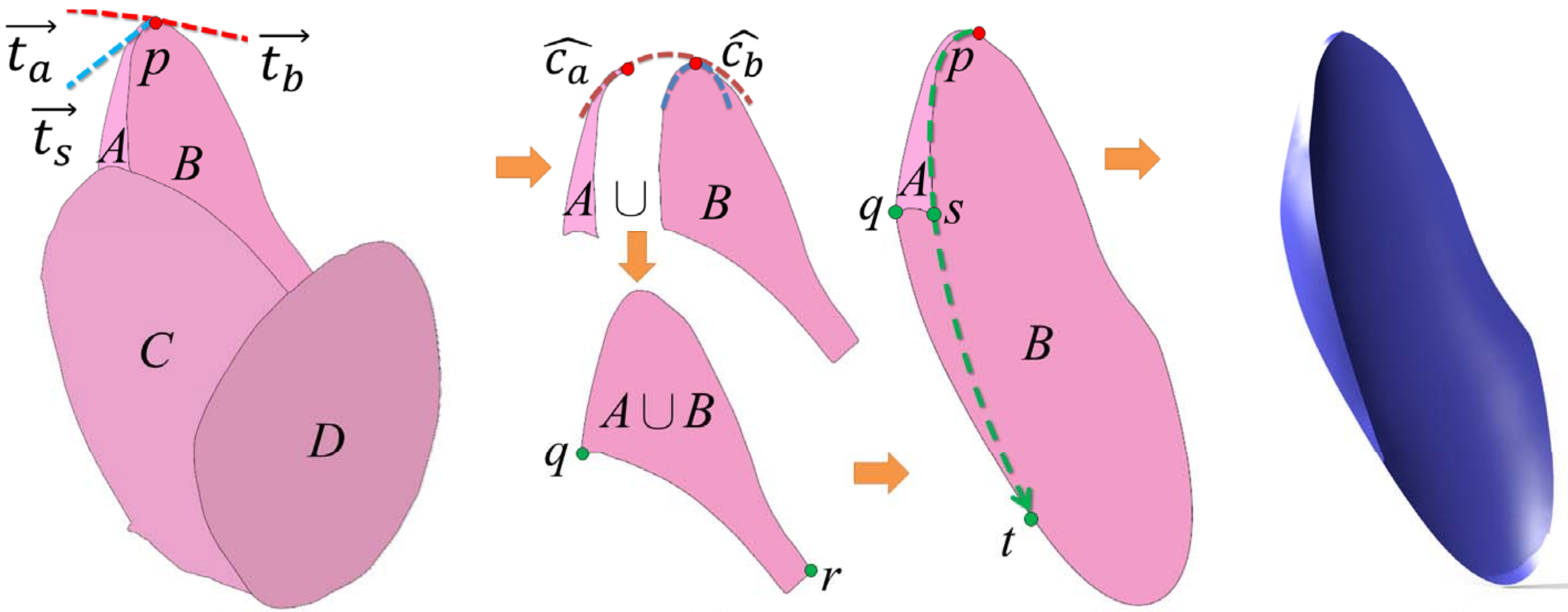
(a)



Completion

- Case (iii): Double-sided structures.

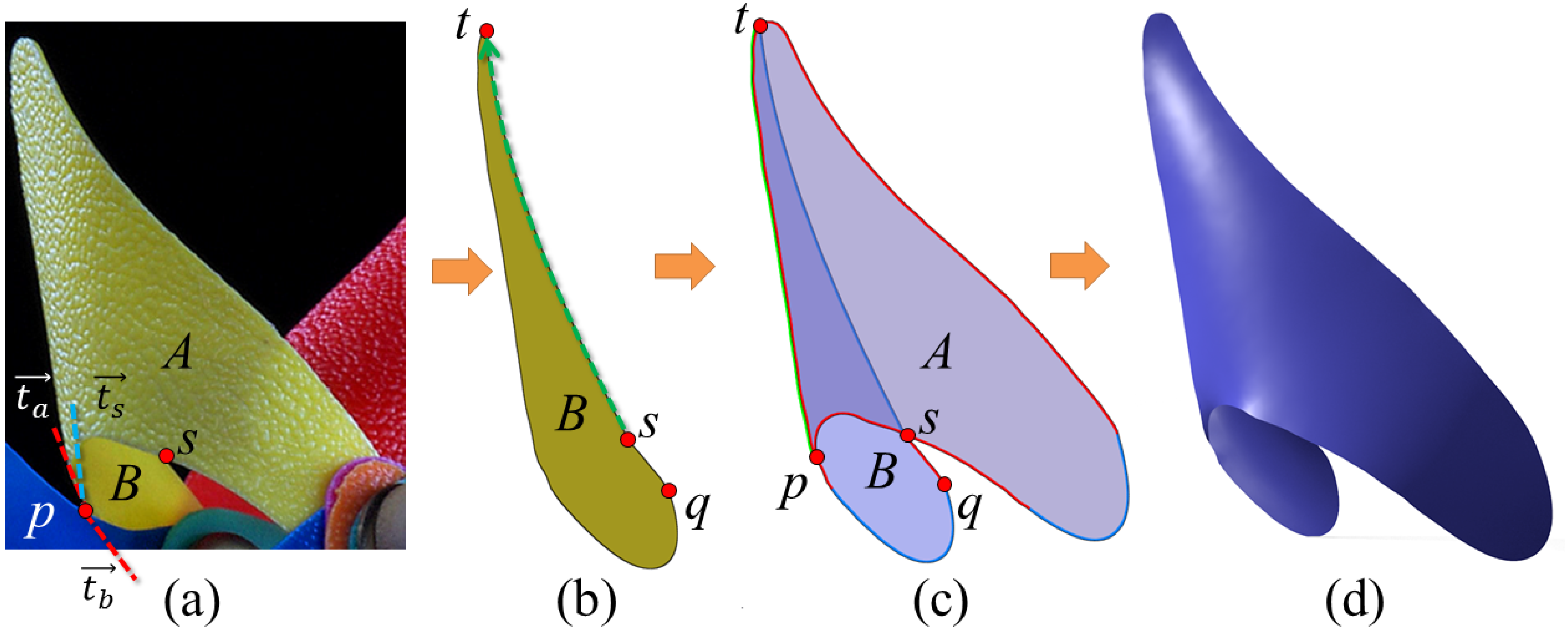
$\theta_a + \theta_b \leq \pi$ and $\widehat{c_a}$ and $\widehat{c_b}$ are C^1 continuous



(a) (b) (c) (d)

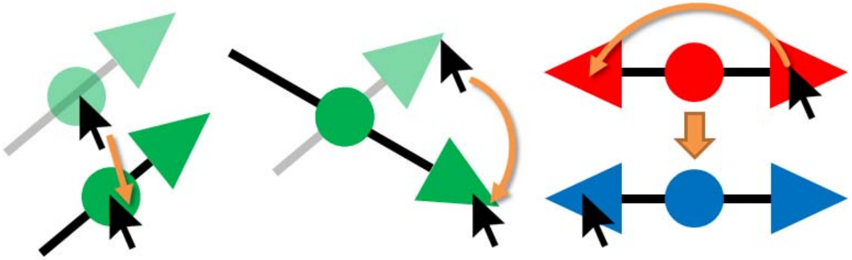
Completion

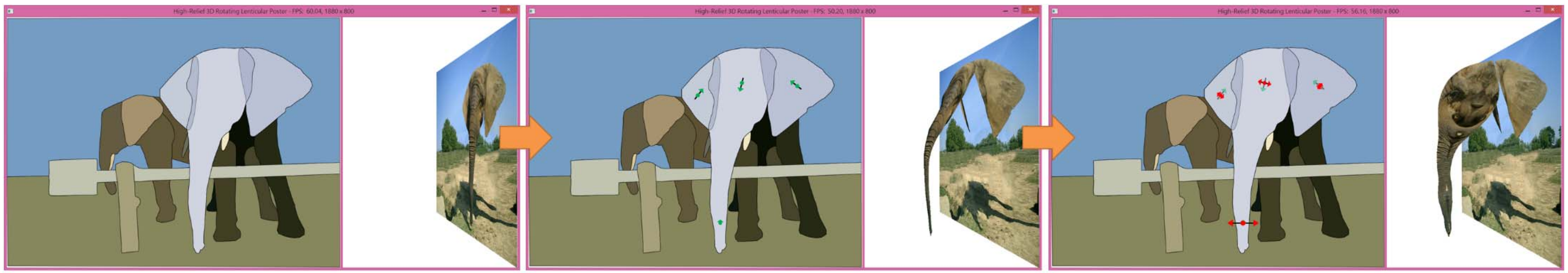
- Case (iii): Double-sided structures.
  - Folded structure



System Overview

Icon	Meaning
	Local slope along the out-of-image direction (+Z-axis)
	Positive mean curvature of surface (convexity)
	Negative mean curvature of surface (concavity)





Inflation

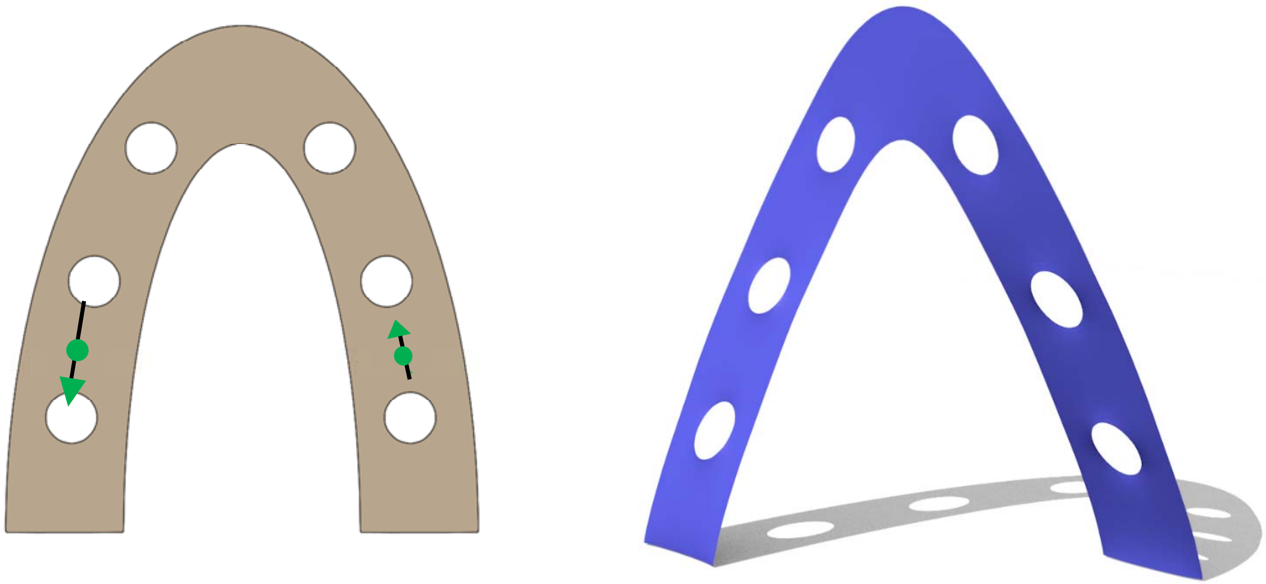
- Compute Z-coordinate of boundary vertices

a planar region $\phi(x, y)$ $\nabla\phi(x, y) = \vec{\Phi}$

$$\min_{\vec{\Phi}} \iint_{\Omega} \left|\nabla\vec{\Phi}\right|^2 + \left|\nabla \times \vec{\Phi}\right|^2 dx\, dy.$$

subject to

$\vec{\Phi}(x_i, y_i) = \vec{s_i}$, where $\{(x_i, y_i, \vec{s_i})\}$ denotes the set of slope cues in $\phi(x, y)$



Inflation

- Compute Z-coordinate of interior vertices.

a set of regions $\{\phi_i\}$ within each region

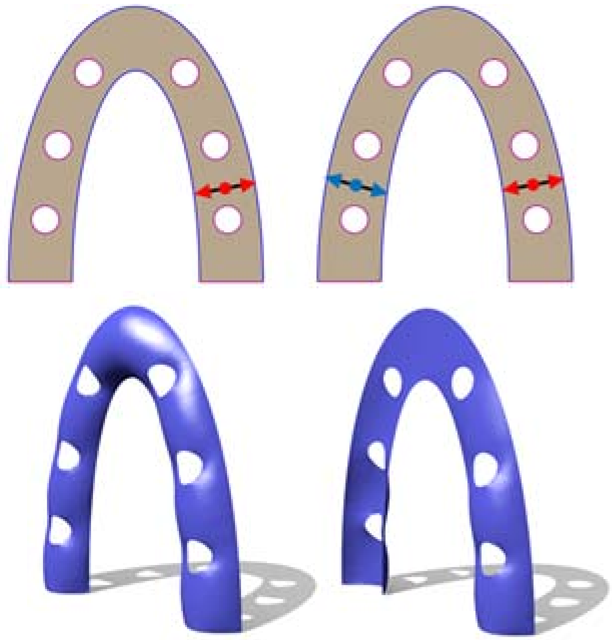
$f^* = \bigoplus_{i=1}^{m} \phi_i$

$\nabla^2 \kappa = 0$ and $\nabla^2 f = \kappa$ $\quad H_\kappa = \{\kappa_i\}$

$$\min_f \int_\Omega \left|\nabla^2 f - \kappa\right|^2 dA$$

subject to:

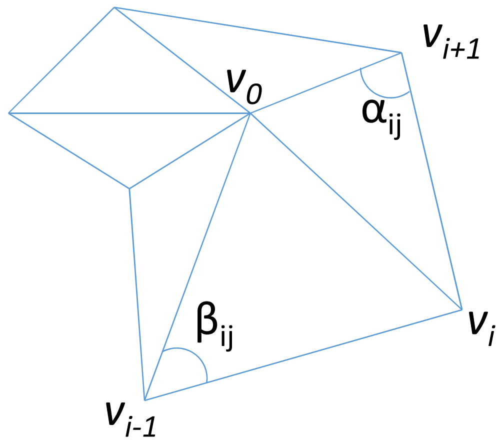
$$f(x) = f^*(x) \qquad \forall x \in B_D,$$
$$\nabla f(x) \cdot \mathbf{n} = 0 \qquad \forall x \in B_N,$$



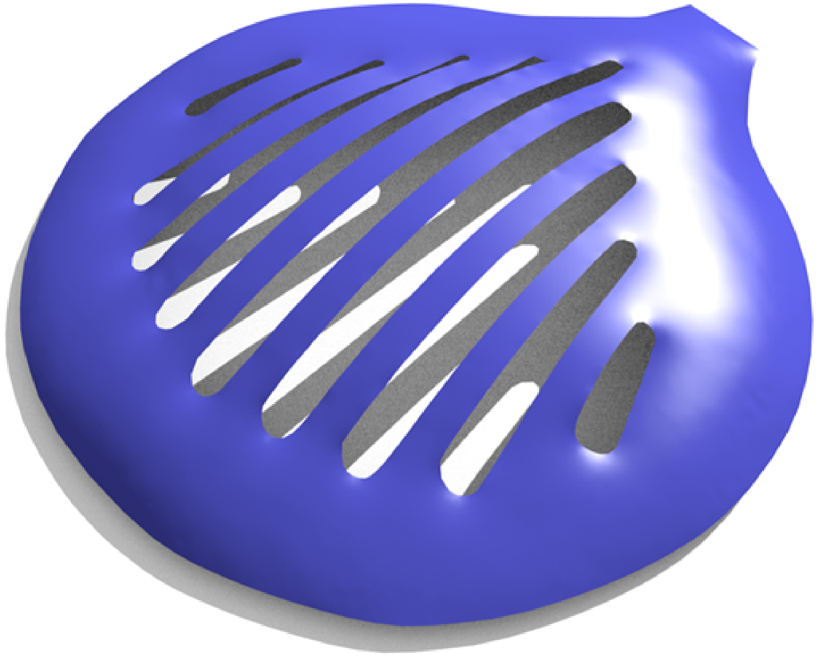
Discrete curvature

$$\kappa\vec{n} = \frac{1}{4A}\sum_{v_j \in N(v_i)} (\cot\alpha_{ij} + \cot\beta_{ij})(v_i - v_j)$$

$$\sum_{\widehat{\kappa}_j \in N(\widehat{\kappa}_i)} (\cot\alpha_{ij} + \cot\beta_{ij})(\widehat{\kappa}_i - \widehat{\kappa}_j) = 0$$



Sample result

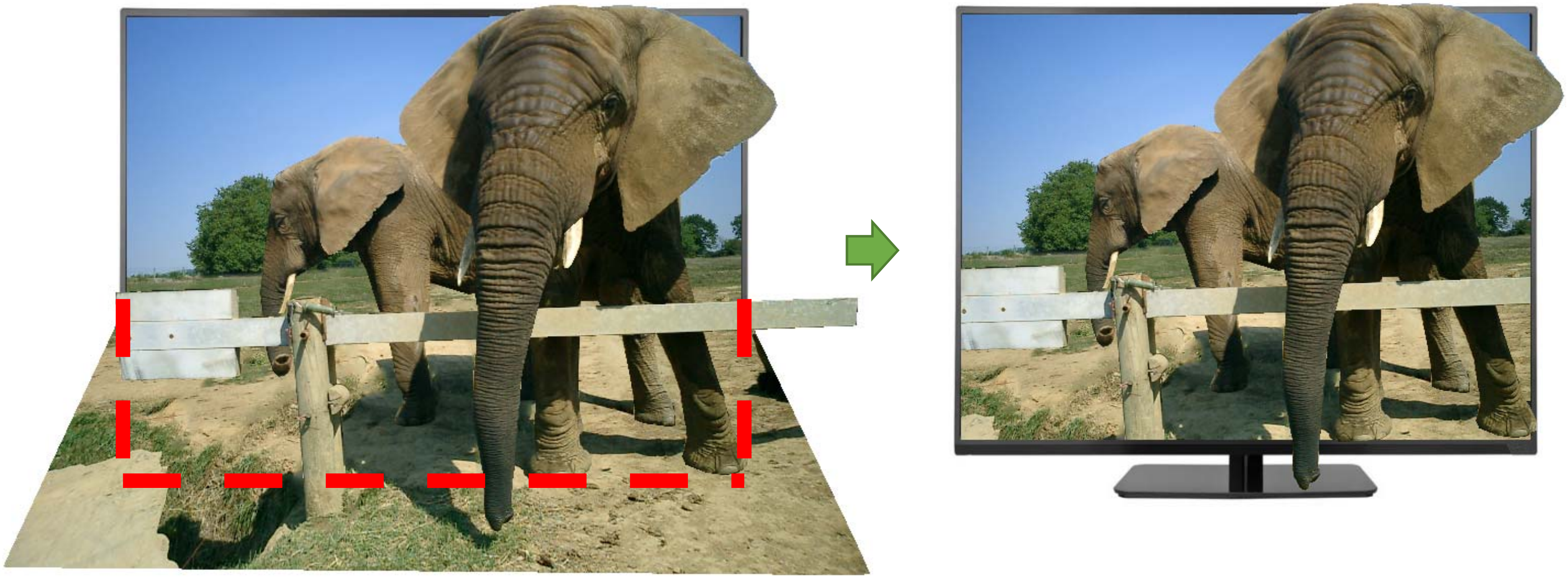


Stitching

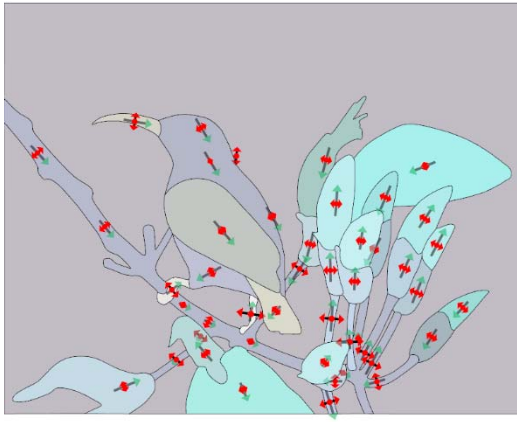
$$\min_{f'} \sum_i \left\{ \int_\Omega |\nabla f_i - \nabla f'_i|^2 + \left| f'_i - f'_{j \in N(i)} \right|^2 dA \right\}$$

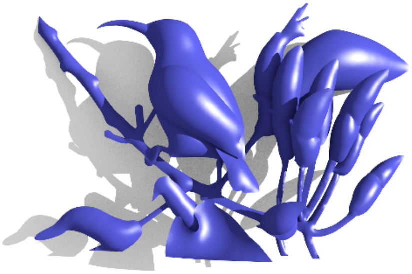
$$f'_i(v_a) \leq f'_j(v_b) \quad \forall (v_a, v_b) \in \{Front(f'_i) \leq Back(f'_j)\},$$
$$f'_i(v_a) = f'_j(v_b) \quad \forall (v_a, v_b) \in Stitch(i, j),$$

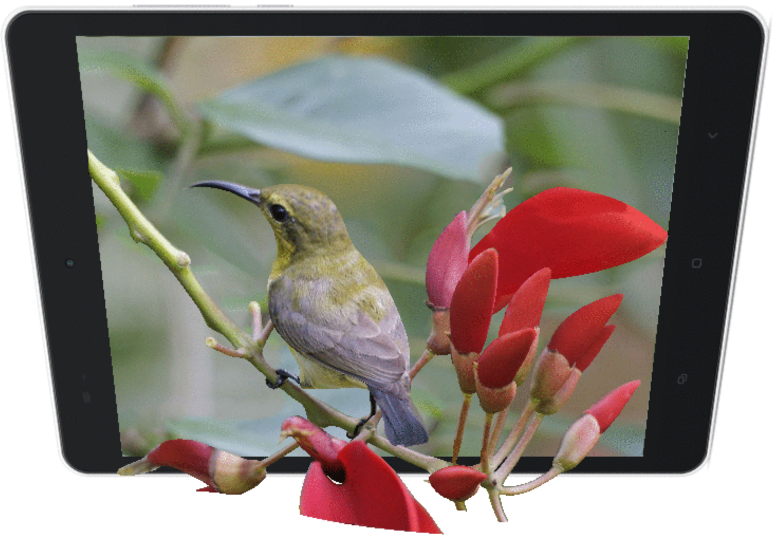
Post – processing



Result







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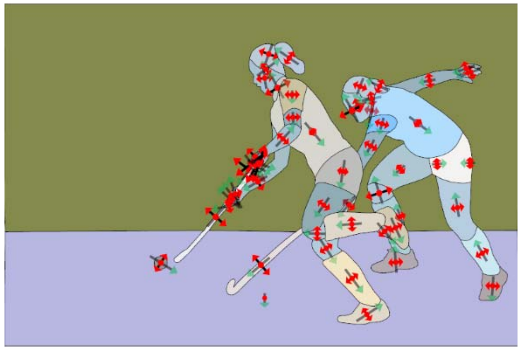

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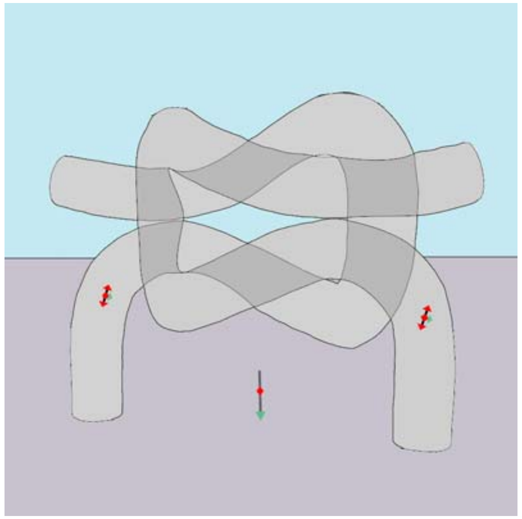

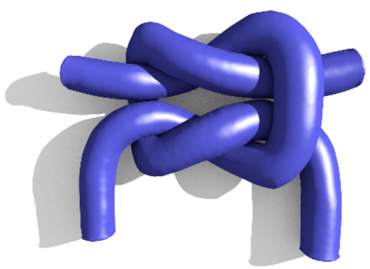

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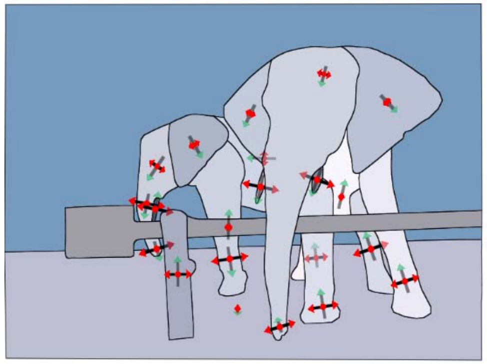
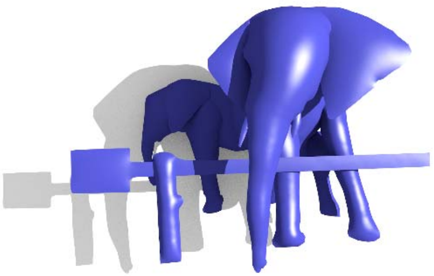
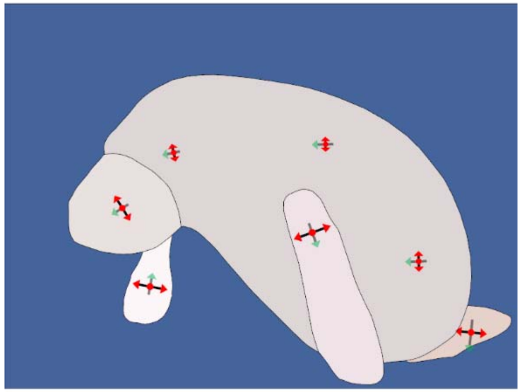
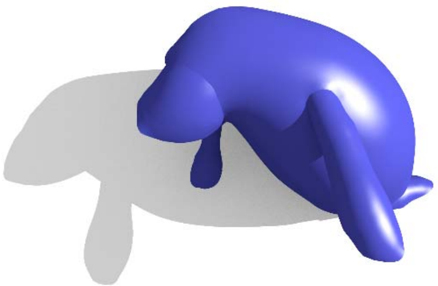




Result

Result





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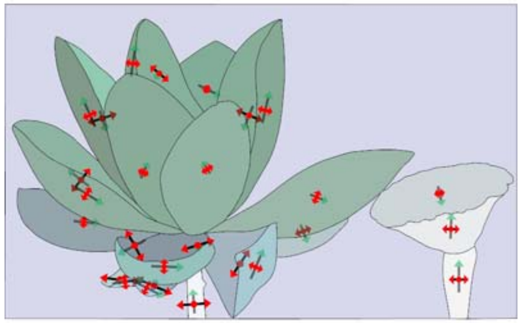

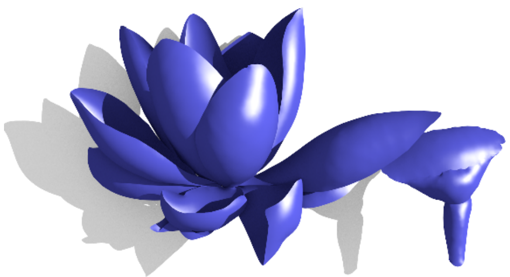

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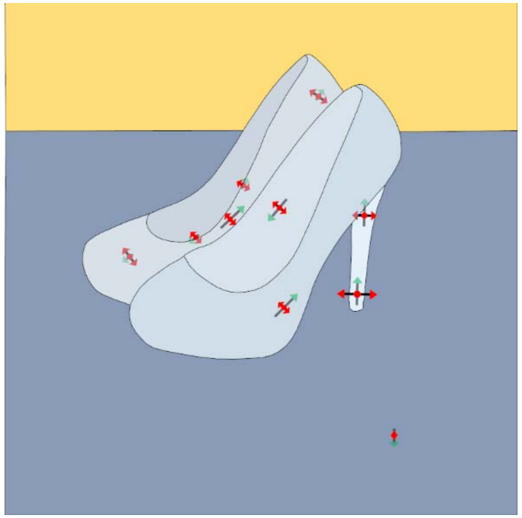

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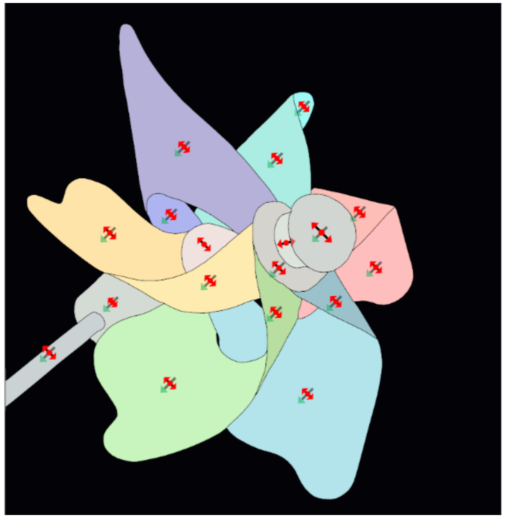
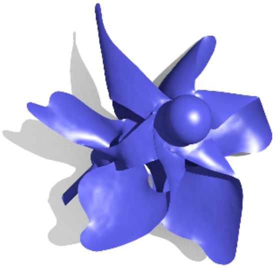
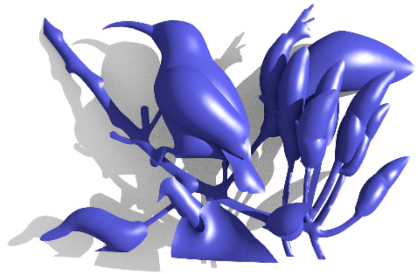
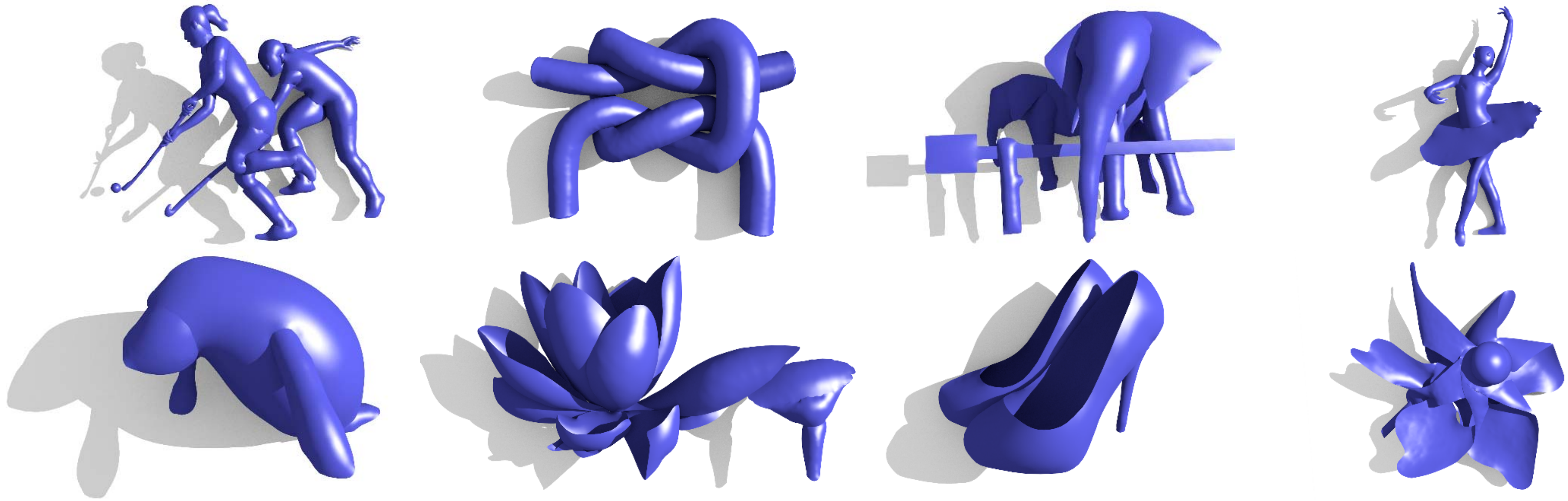




Performance

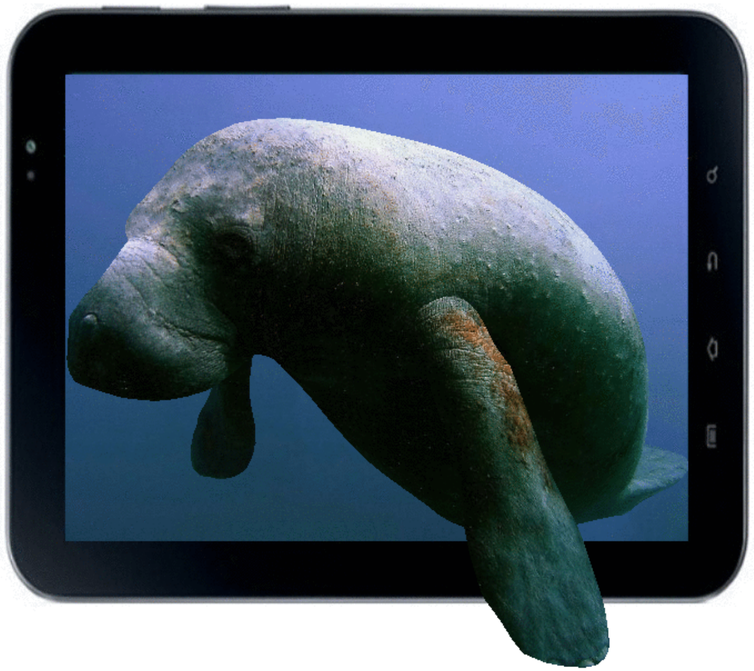




Inputs	# Triangles	Segmentation		Layering	Completion	Inflation				Stitching	Total time
						# Slope & Curvature Cues	Average Compute Time per Region		User annotation		
		# Regions	Time				Slope	Curvature			
Bird (Fig. 2)	36846	31	9m 51s	0.029s	2.051s	34	0.0258s	0.2133s	4m 40s	1m 8s	15m 41s
Hockey (Fig. 13, row 1)	52396	53	10m 20s	0.050s	3.682 s	53	0.0248s	0.1615s	6m 1s	2m 5s	18m 30s
Knot (Fig. 13, row 2)	37178	4	5m 45s	0.014s	1.007s	3	0.0787s	0.4889s	0m 23s	0m 45.3s	6m 54s
Elephant (Fig. 13, row 3)	32948	18	12m 31s	0.018s	1.391s	21	0.0299s	0.2565s	2m 45s	1m 2s	16m 19s
Ballet (Fig. 13, row 4)	33180	23	5m 12s	0.024s	1.503s	30	0.0507s	0.2213s	3m 48s	0m 40.7s	9m 42s
Seacow (Fig. 13, row 5)	24842	5	2m 33s	0.009s	0.308s	7	0.0612s	0.4264s	0m 45s	0m 35.8s	3m 54s
Flower (Fig. 14, row 1)	36597	26	4m 59s	0.021s	1.659s	26	0.1279s	0.4830s	3m 10s	0m 39.2s	8m 50s
Shoes (Fig. 14, row 2)	10974	8	2m 24s	0.008s	0.325s	10	0.0777s	0.5301s	1m 15s	0m 10.3s	3m 50s
Pinwheel (Fig. 14, row 3)	23983	18	6m 17s	0.014s	1.473s	18	0.1403s	0.4465s	2m 53s	0m 10.1s	9m 22s

Result & Discussion

- Comparison: Compare with 2014-Ink-and-Ray Bas-Relief Meshes for Adding Global Illumination Effects to Hand-Drawn Characters



Result & Discussion

- Comparison: Compare with 2015-Hallucinating-stereoscopy-single-image

Result & Discussion

- Comparison: Compare with 2015-Hallucinating-stereoscopy-single-image

Conclusion

- 2.5D Cartoon Hair Modeling and Manipulation
  - We have presented a novel 2.5D approach to modeling, animating, and manipulating hairs in a single cartoon image.
  - We derive an effective layering metric from the Gestalt psychology and our observation on cartoon images
  - We develop a novel layer completion method that can automatically fill the occluding parts of hair strands
  - We devise a simplified simulation model to animate the skeletons in hair strands, including hair editing and hair braiding.

Conclusion

- Interactive High-Relief Reconstruction for Organic and Double-sided Objects from a Photo
  - Just input a single image.
  - We have reconstruct high-relief 3D models
  - Images consider common organic objects with nontrivial shape profile and the reconstruction of objects composed of double-sided structures.

Future Work

- We plan to extend our 2.5D layering model to support local layering.
- We would like to explore ways to produce pseudo 3D effect.
- We plan to study rendering methods to add shadows for 2.5D models.
- We plan to automate the estimation of slope and curvature cues from the image contents.

Acknowledgements

- Adviser:
  - Prof. Tong-Yee Lee
- Collaborators
  - Prof. Chi-Wing Fu (Philip)
  - Prof. Chao-Hung Lin
  - Peng Song
  - Peng-Yen Lin
  - Pradeep Kumar Jayaraman
  - Xiaopei Liu
- NCKU Visual System LAB

References

- Chih-Kuo Yeh, Shi-Yang Huang, Pradeep Kumar Jayaraman, Chi-Wing Fu and Tong-Yee Lee, “Interactive High-Relief Reconstruction for Organic and Double-sided Objects from a Photo.” IEEE Transactions on Visualization and Computer Graphics, vol. 23, no. 7, pp. 1796-1808, July 1 2017. (SCI)
- Chih-Kuo Yeh, Pradeep Kumar Jayaraman, Xiaopei Liu, Chi-Wing Fu and Tong-Yee Lee, "2.5D Cartoon Hair Modeling and Manipulation." IEEE Transactions on Visualization and Computer Graphics, vol. 21, no. 3, pp. 304–314, 2015. (SCI)
- Chih-Kuo Yeh, Peng Song, Peng-Yen Lin, Chi-Wing Fu, Chao-Hung Lin and Tong-Yee Lee, “Double-sided 2.5D Graphics.” IEEE Transactions on Visualization and Computer Graphics, 19.2 (2013): 225-235. (SCI)

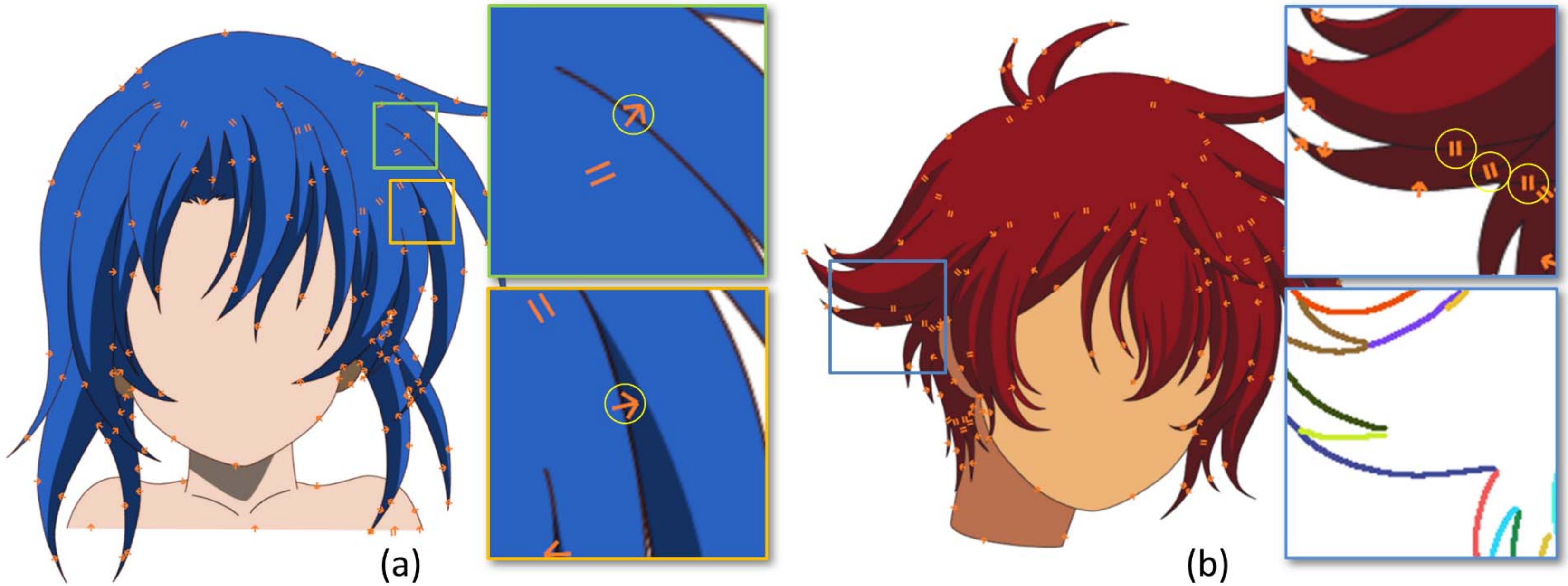
Thank You!

Q & A

Backup Slides

Template Modeling

Limitations



Accuracy of our layering metric

cartoon images (see Fig. 11)	accuracy (vs G.T.)		average time (sec.)	
	subjects	our metric	subjects	our metric
First row	90.1%	91.4%	192.0	0.031
Second row	92.3%	93.5%	382.1	0.042
Third row	95.9%	97.0%	216.7	0.032
Fourth row	90.7%	92.3%	231.2	0.020
Average	92.3%	93.6%	255.5	0.031

Performance

- 3.4 GHz CPU and 4GB memory.
- Layering computation, 0.031 seconds
- Hair completion (excluding texture inpainting) 1.608 seconds
- Skeleton generation 0.415 seconds
- Deformation 0.015 seconds
- Segmentation :

8 minutes

12 minutes

9 minutes

15 minutes

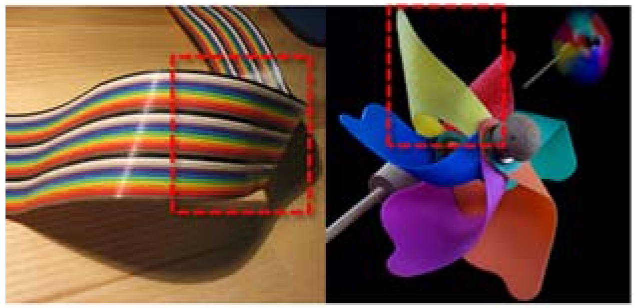
Failure texture synthesis

Failure segmentation

Methodology

Completion

- Case (i): Expand a single region from the occluding boundary



Result & Discussion

- Limitation