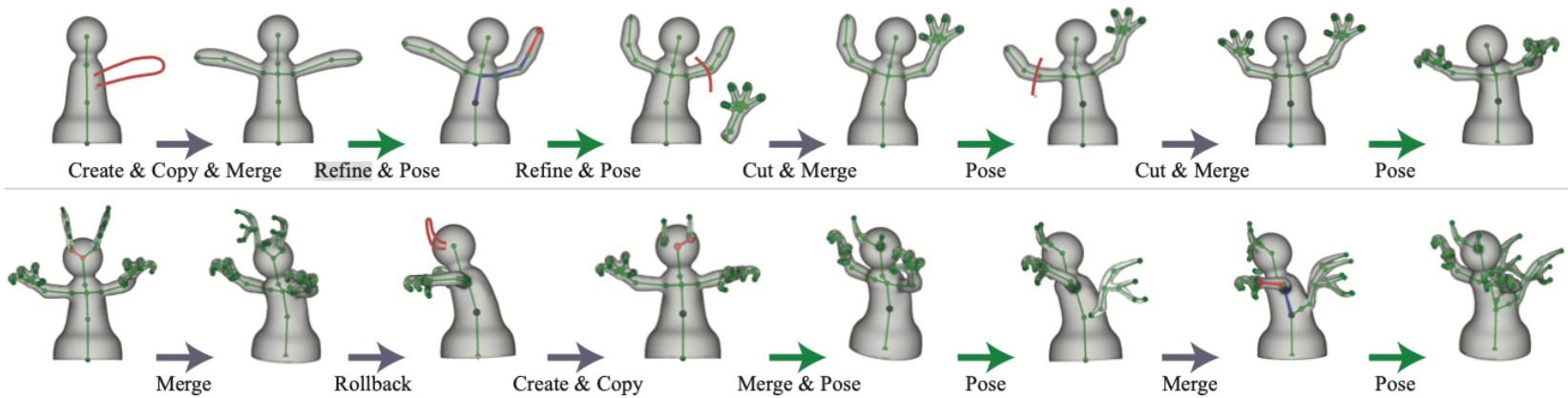
RigMesh: Automatic Rigging for Part-Based Shape Modeling and Deformation

Duc Nguyen

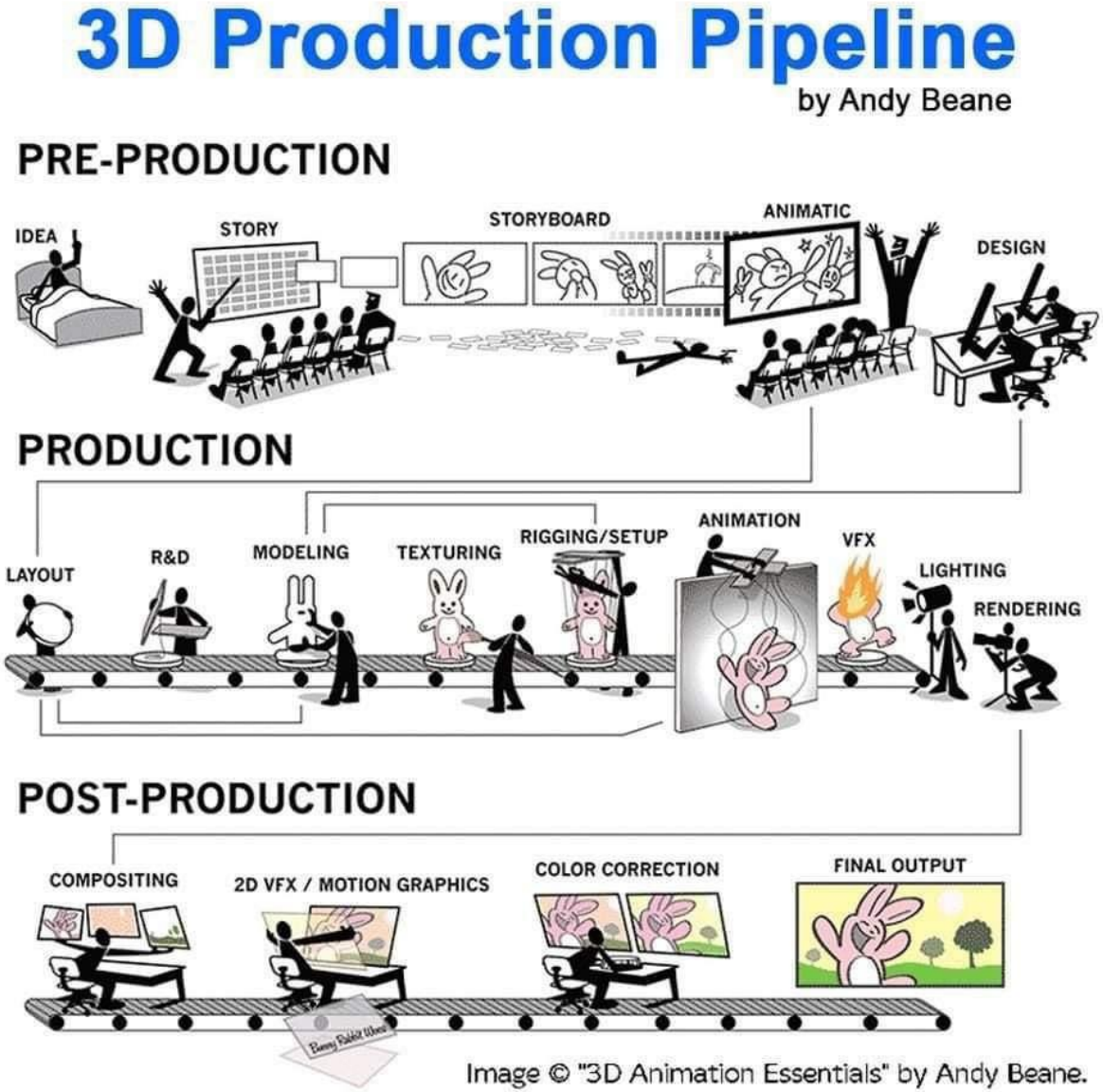
Telecom Paris

February 13, 2026

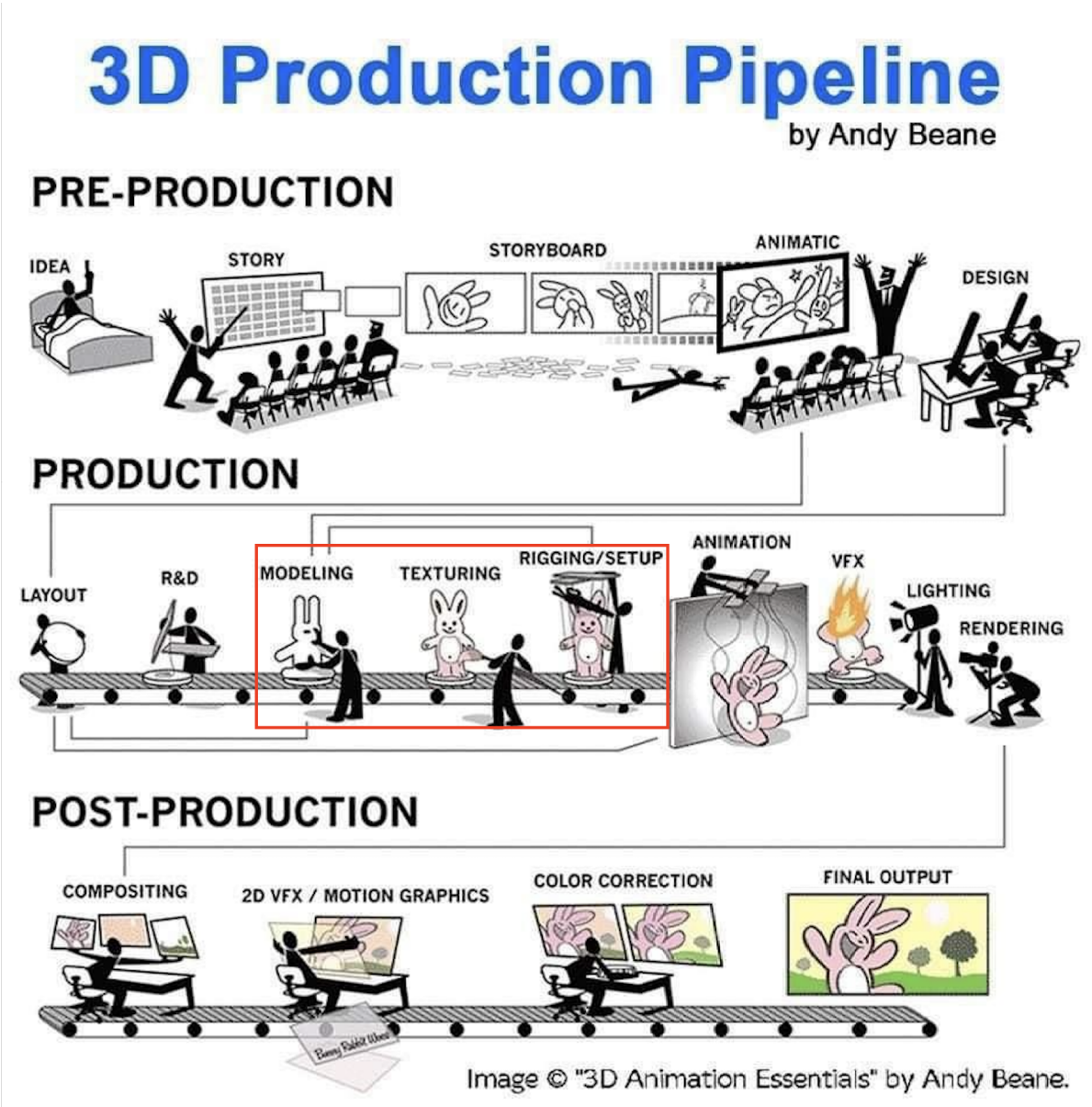


Outline

3D Character Animation Workflow



3D Character Animation Workflow



Main contribution

- Unify modeling and rigging steps, avoiding recurring step of geometry validation after rigging.
- Modify the Douglas-Peucker algorithm [1973] to create a high-quality skeleton from the sketched outline of a shape.
- Propose method to re-compute skin weights efficiently.

Workflow

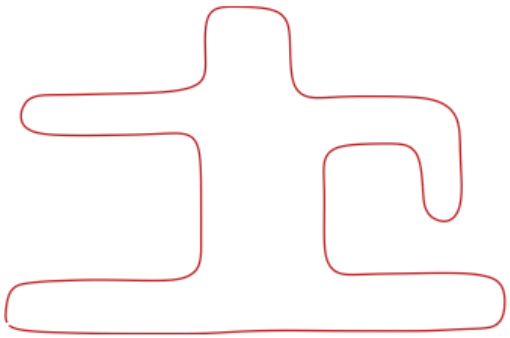


Figure 1: Input silhouette

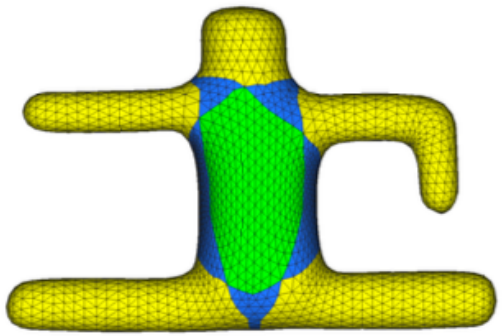


Figure 2: Mesh surface

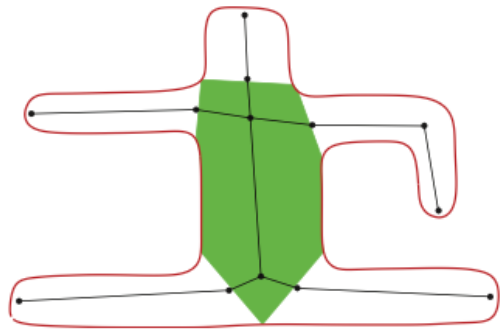
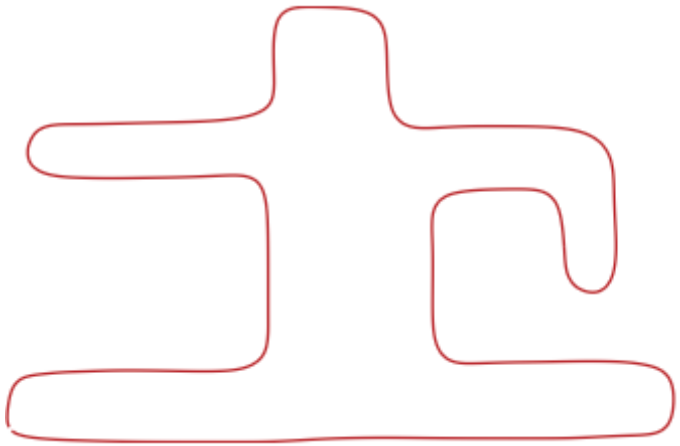


Figure 3: Skeleton + Skin weights

Surface Generation

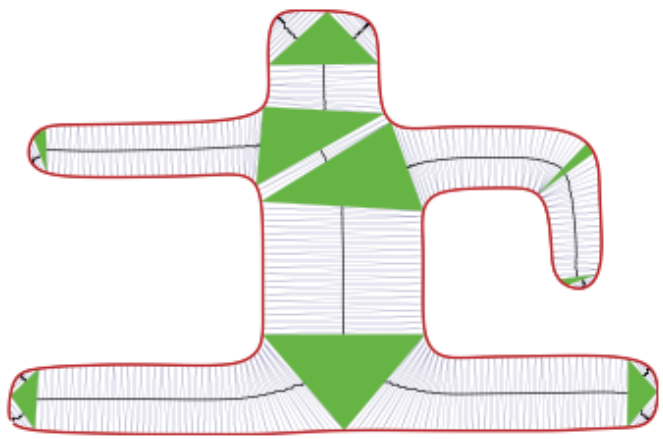
From silhouette to body-part decomposation:
Chordal Axis Transform [Prasad, 2007]:

- Use Constrained Delaunay Triangulation [Chew, 1987]
- Internal edges are referred as "chord"



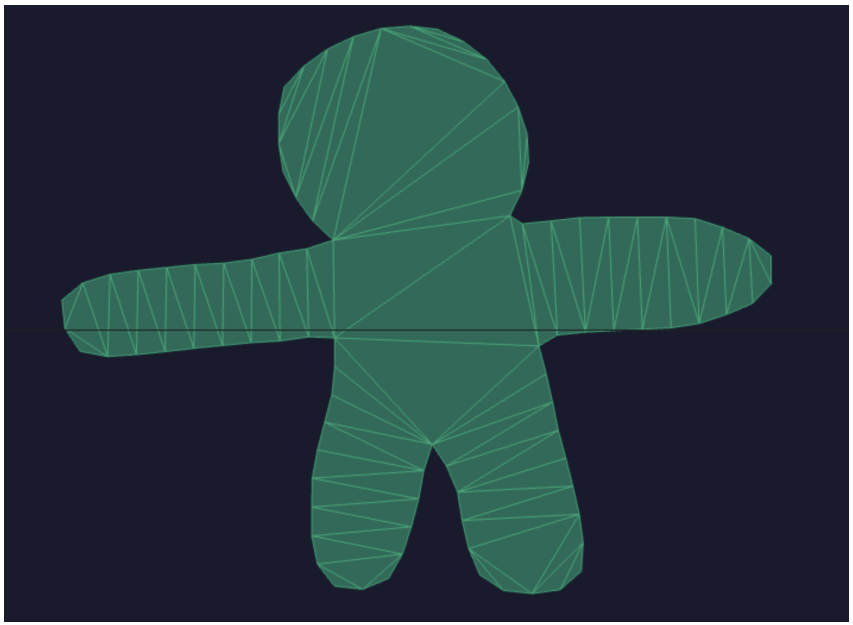
The silhouette is now partitioned into 3 parts:

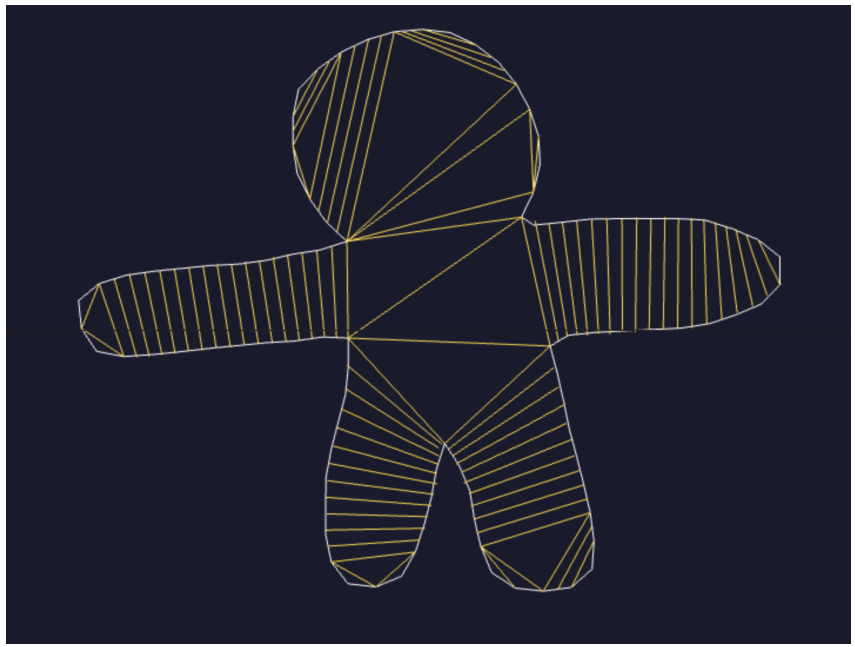
- **Pipe**: Regions containing only chords.
- **Junction**: Triangles incident to 3 chords.
- **Cap**: Triangles incident to only 1 chord.



Surface Generation

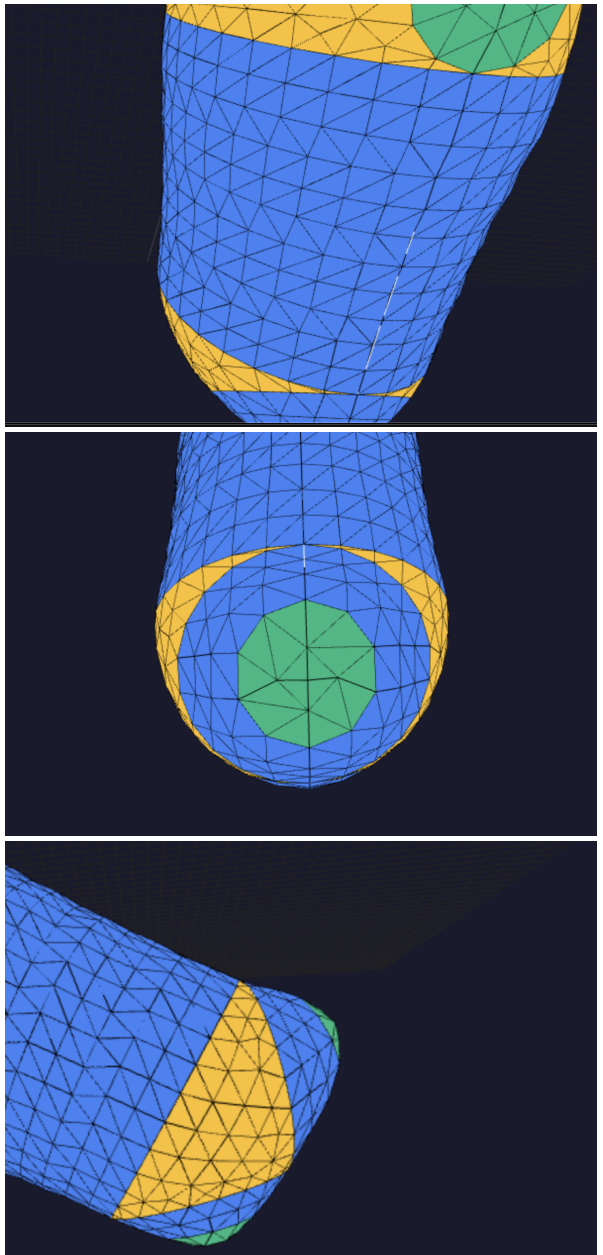
Noise reduction: Apply Laplacian smoothing to chordal axis and chordal orientation.



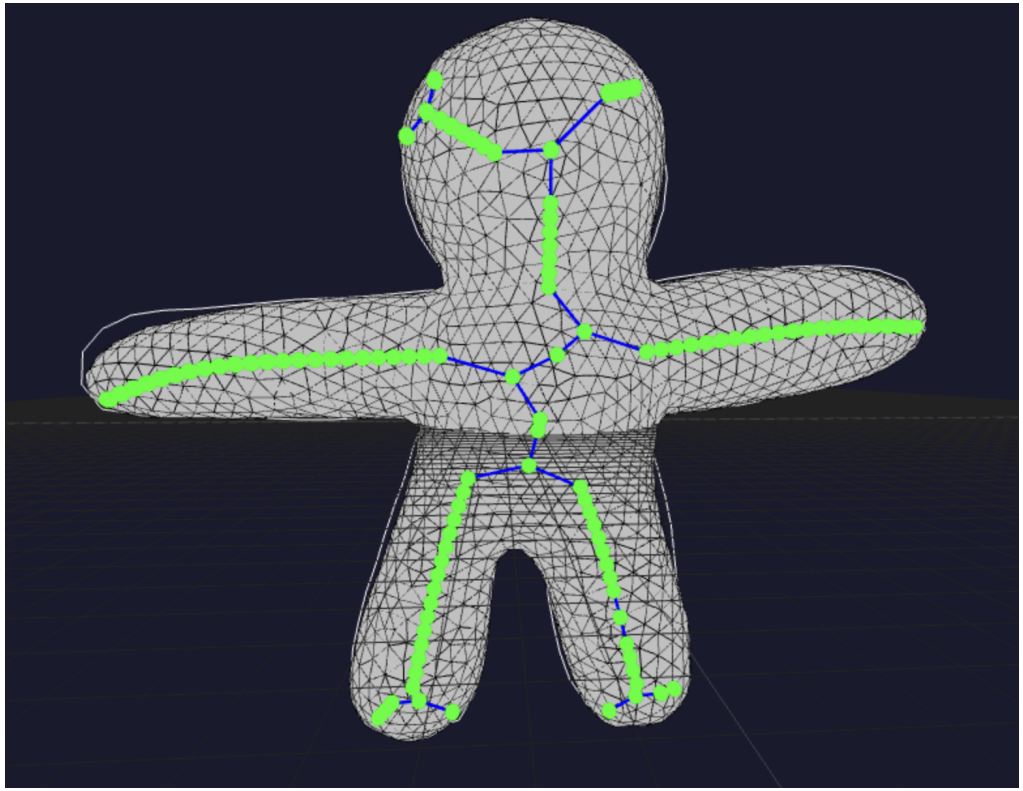


Surface Generation

Pipe: Generate a disc for each chord, then stitch two consecutive discs together to form a slice of a larger cylinder.
Cap: Generate new virtual chords by simultaneously decreasing both its length and adjusting its axis toward the corner. Then apply the same pipe generation process.
Junction: Use *GridMesh [Nealen et al., 2009]* to generate a 2D patch, then apply *Least-Squares Meshes [Sorkine and Cohen-Or, 2004]* to recompute point positions and inflate the patch.



Skeleton Generaton

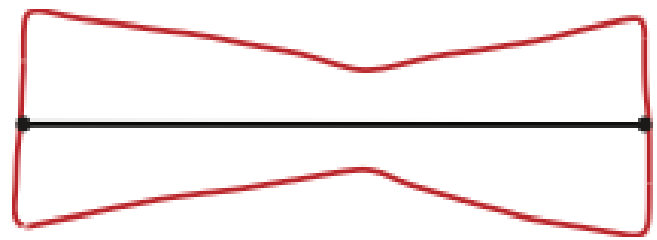


- Downsample the chordal axis to joints & bones.
- As easy as detecting "salient" point on the chordal axis.

Skeleton Generation: Decolinearization

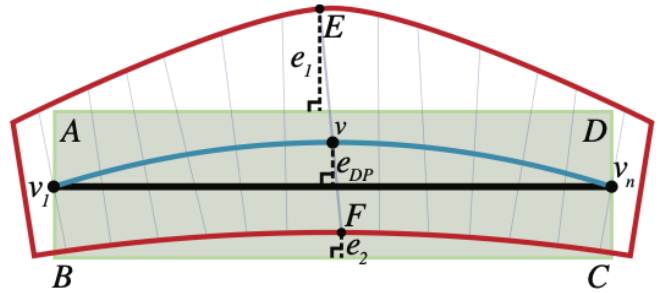
Now we are trying to remove joints on a "almost colinear" joint-chain:

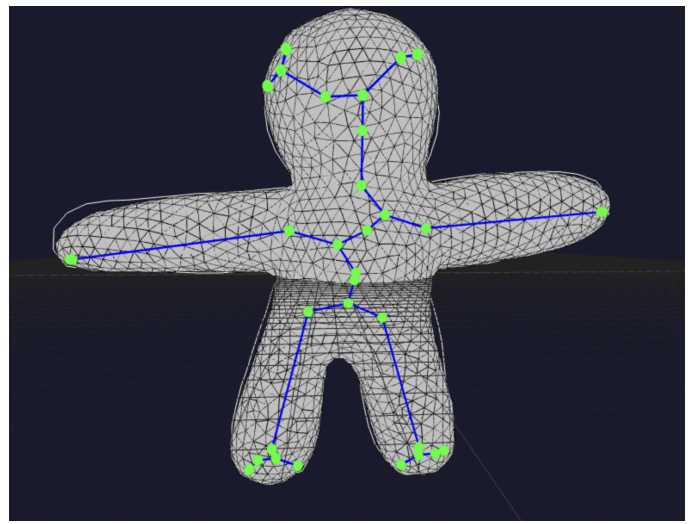
- Douglas-Peucker (DP) algorithm [DOUGLAS and PEUCKER, 1973] finds such points in a greedy manner.
- But this only took into account the shape of chordal axis.
- The author proposed a varient of DP algorithm (Cylindrical DP)



Cylindrical Douglas-Peucker (CDP)

- Iterate though v between v_1 and v_n
- Measure some "error" of point v
- If "error" of all such point v is acceptable (smaller than a threshold), then we can consider v_1 and v_n as 2 joints of a bones.
- Otherwise we make a new joint from the point with greatest "error" measure and recursively continue the process.

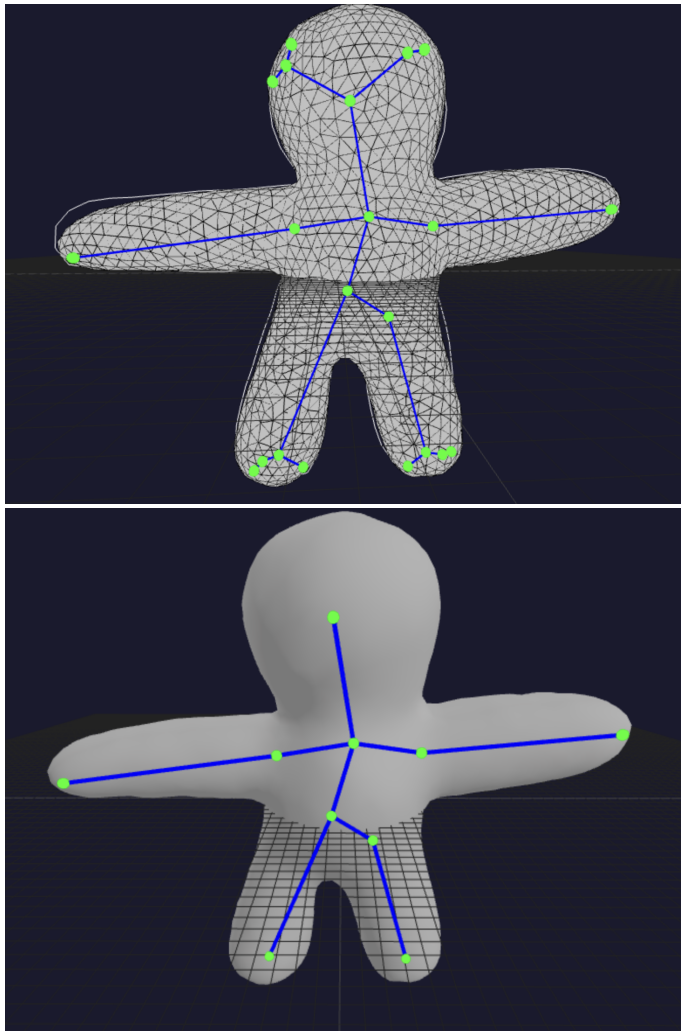




Skeleton Generation: Short bone collapse

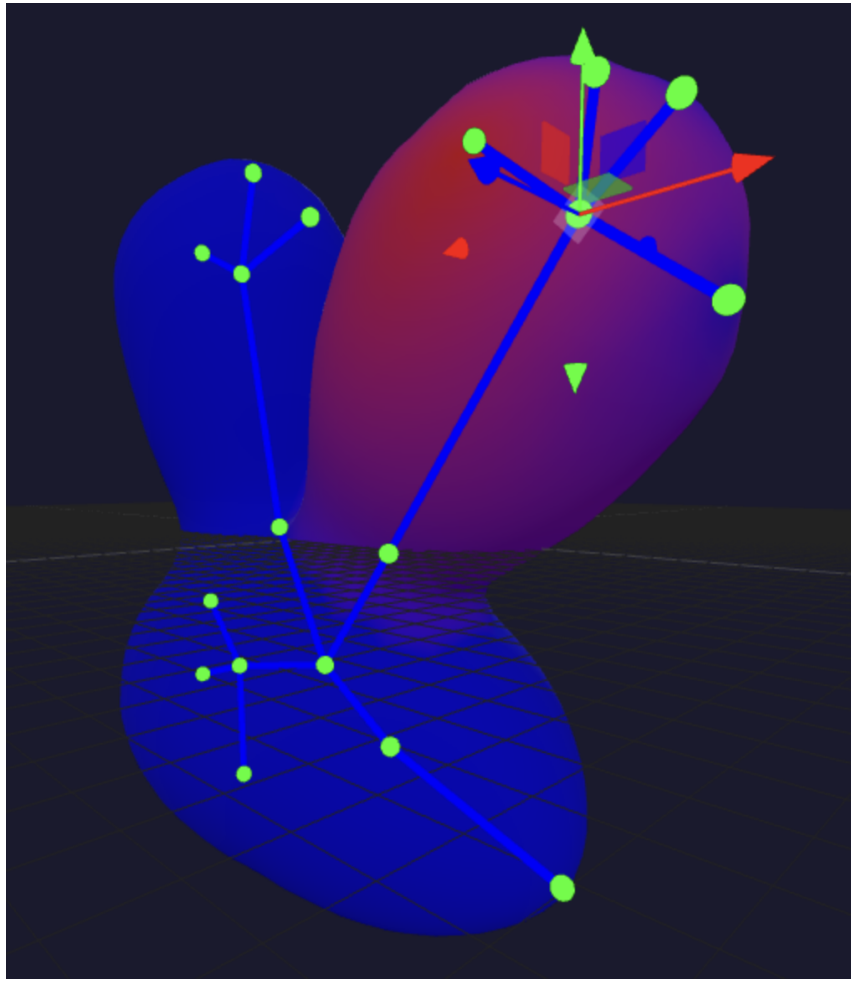
Beyond the chordal axis itself, joints are also placed at the barycenters of *junction triangles*, which are then connected to the chordal axes of the incident chords.

- Short bones that are not located on leaf branches are contracted.
- Short leaf branches are pruned using a breadth-first search (BFS).



Skin weight computation

- Joints "radiate" heat onto the surface.
- The weight of each bone is the temperature at equilibrium state.



Mathematical Tool

There are 2 intensively used equation across the framework:

- Laplacian Smoothing equation:

$$x = \arg\min_x \|Lx\|^2 + \|x - v\|^2 \tag{1}$$

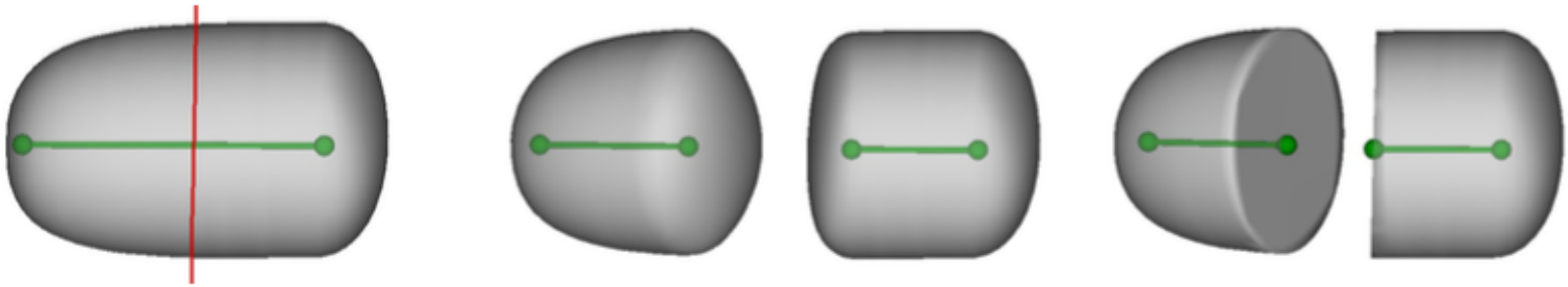
- Heat Diffusing Equation:

$$\frac{\partial w}{\partial t} = Lw + H(p - w) = 0 \tag{2}$$

And this also support some particular constraints:

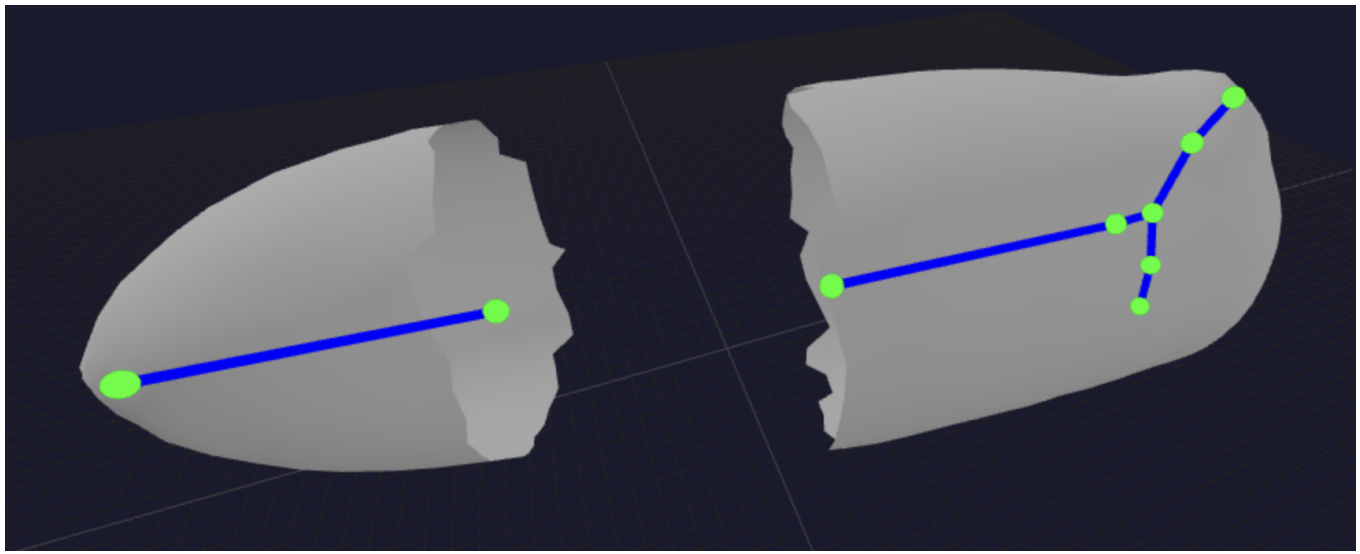
- Weak constraint: It would be nice if x_i is close to v_i
- Hard constraint: x_i must be v_i

Cutting

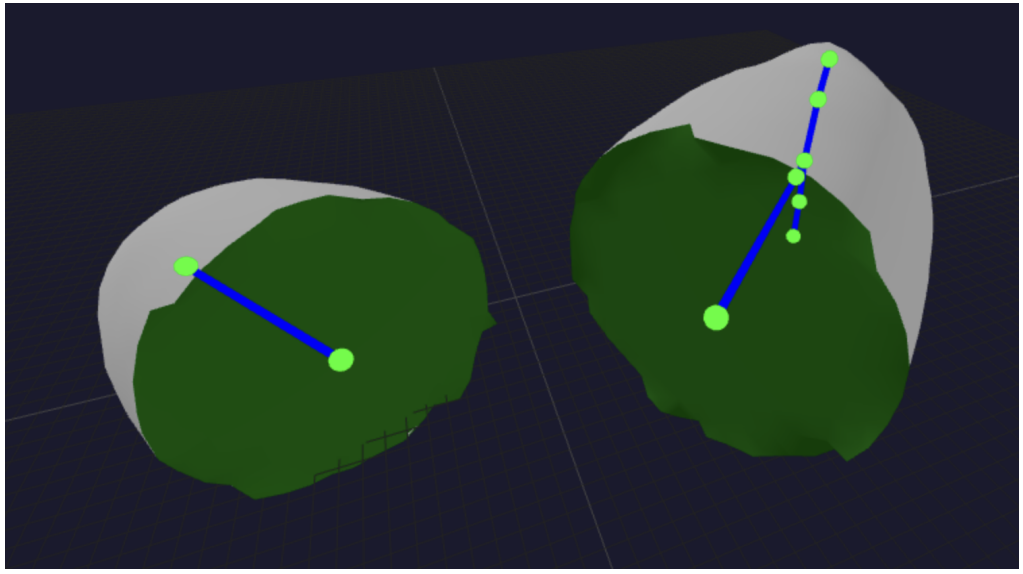


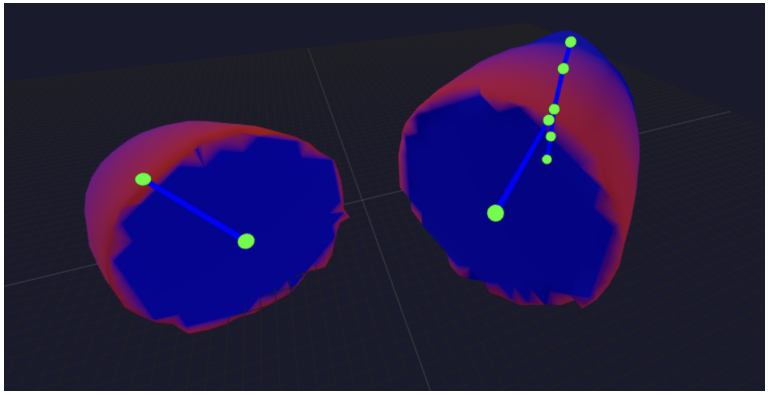
- Splitting the mesh along the drawn curve
- Remove skin weight that correspond to bone not in the meshes.
- Use Least Square Mesh to stitch the two part (weight assigned to constrained using "sharpness" of the cut)
- Calculate skin weights for new vertices by diffusing Laplacian inward to fill the cold patch.
- Normalize skin weights for new and old vertices.

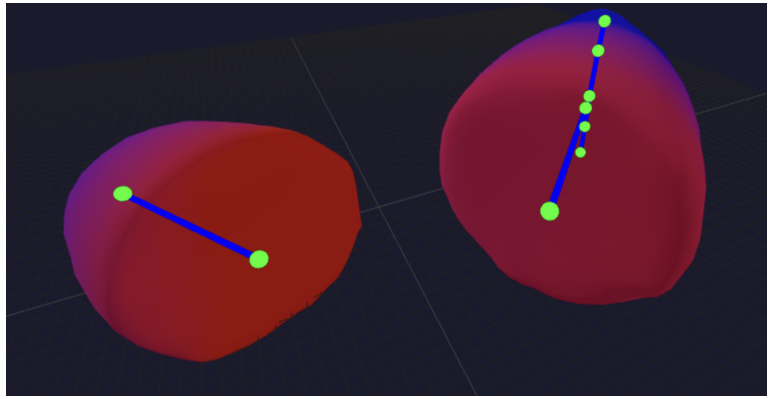
Cutting



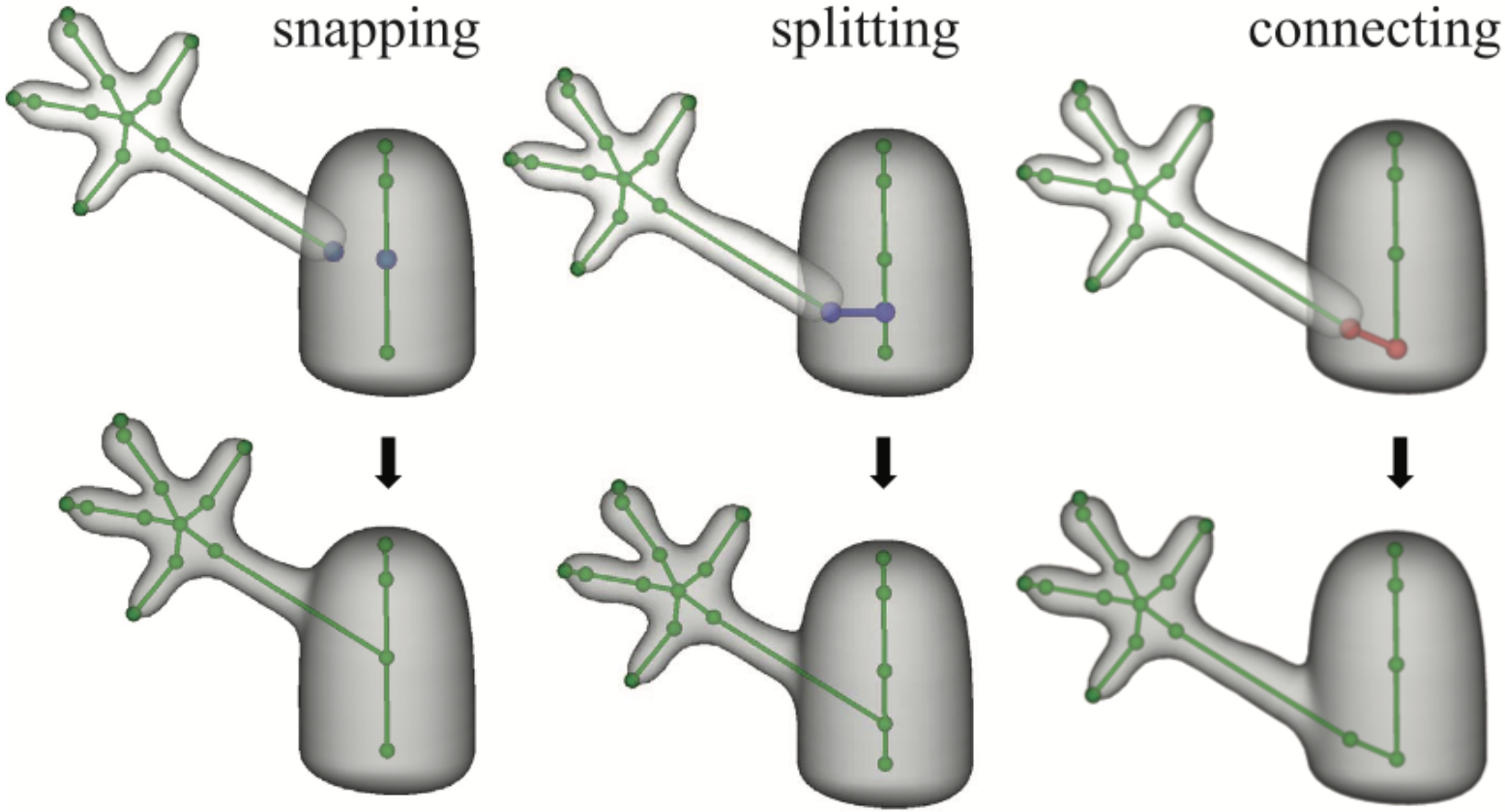
Cutting







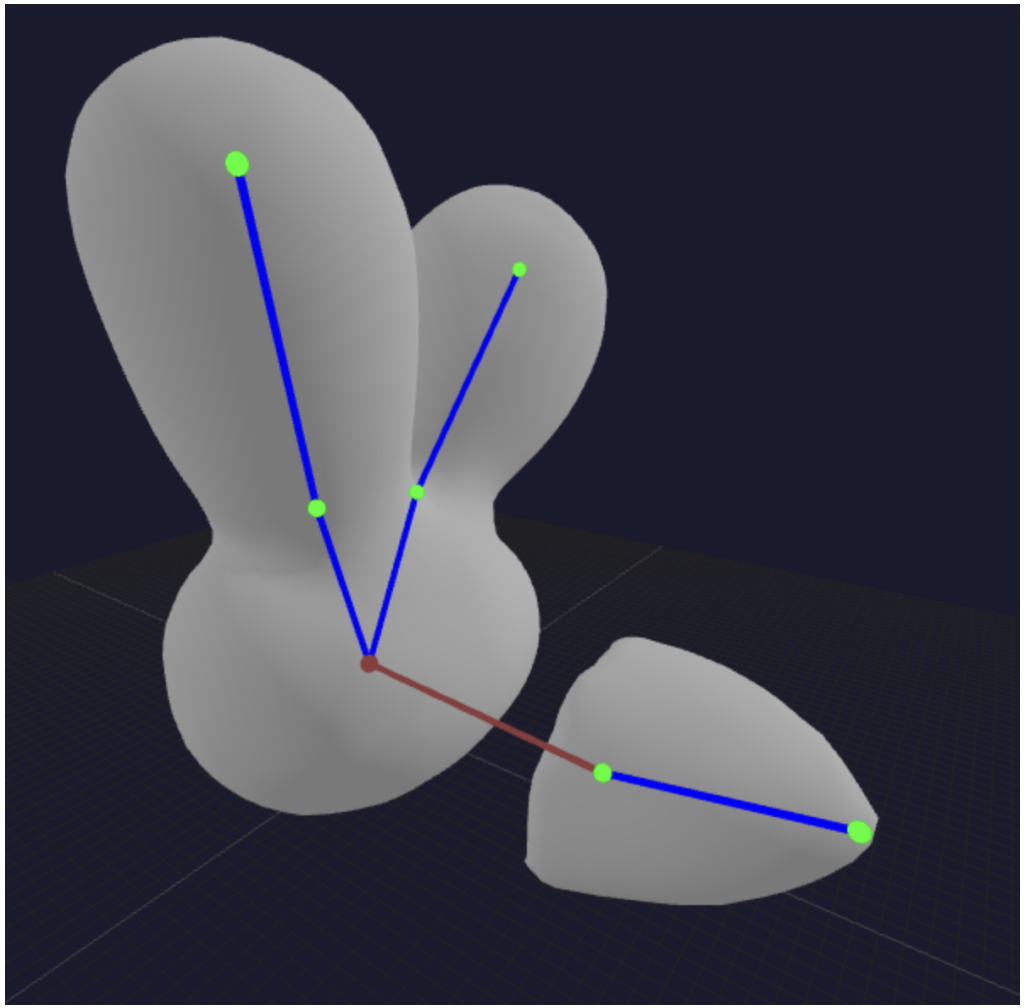
Merging



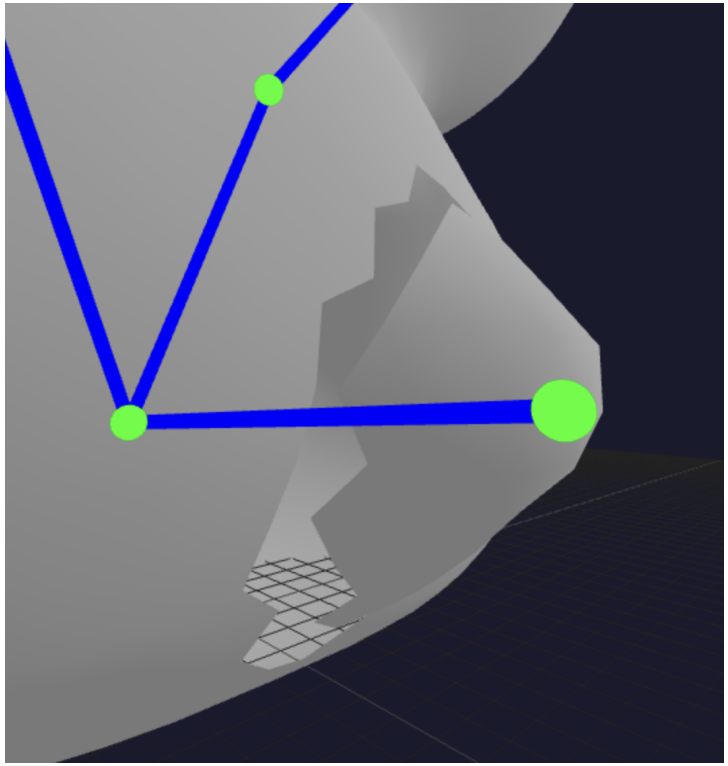
Merging

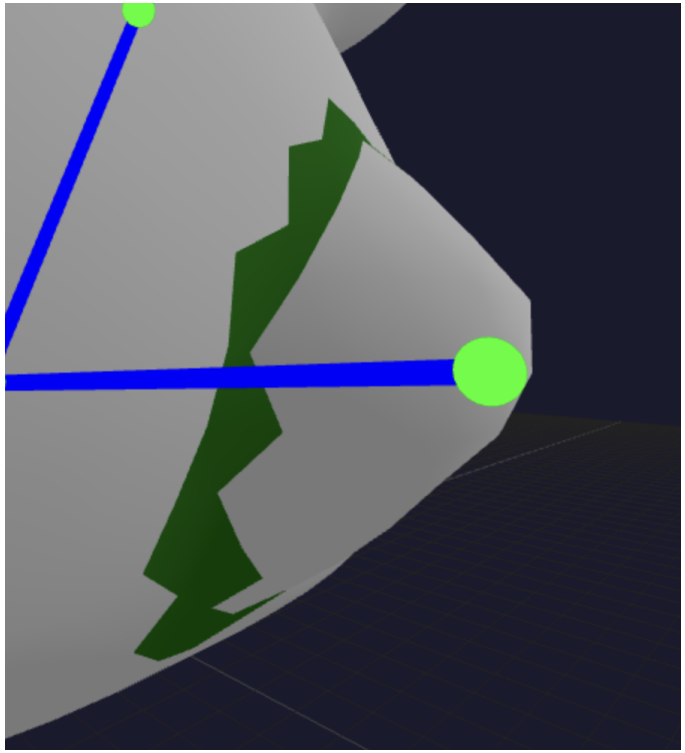
- Triangles from one surface inside the other are discarded.
- The resulting meshes are glued together along the shared boundary (new vertices can be added if necessary).
- Local Laplacian smoothing is performed around the intersection loop.
- Choose a neighborhood around the cut loops to select vertices & bones to do a localized global skin weight re-computation.

Merging: Preparation

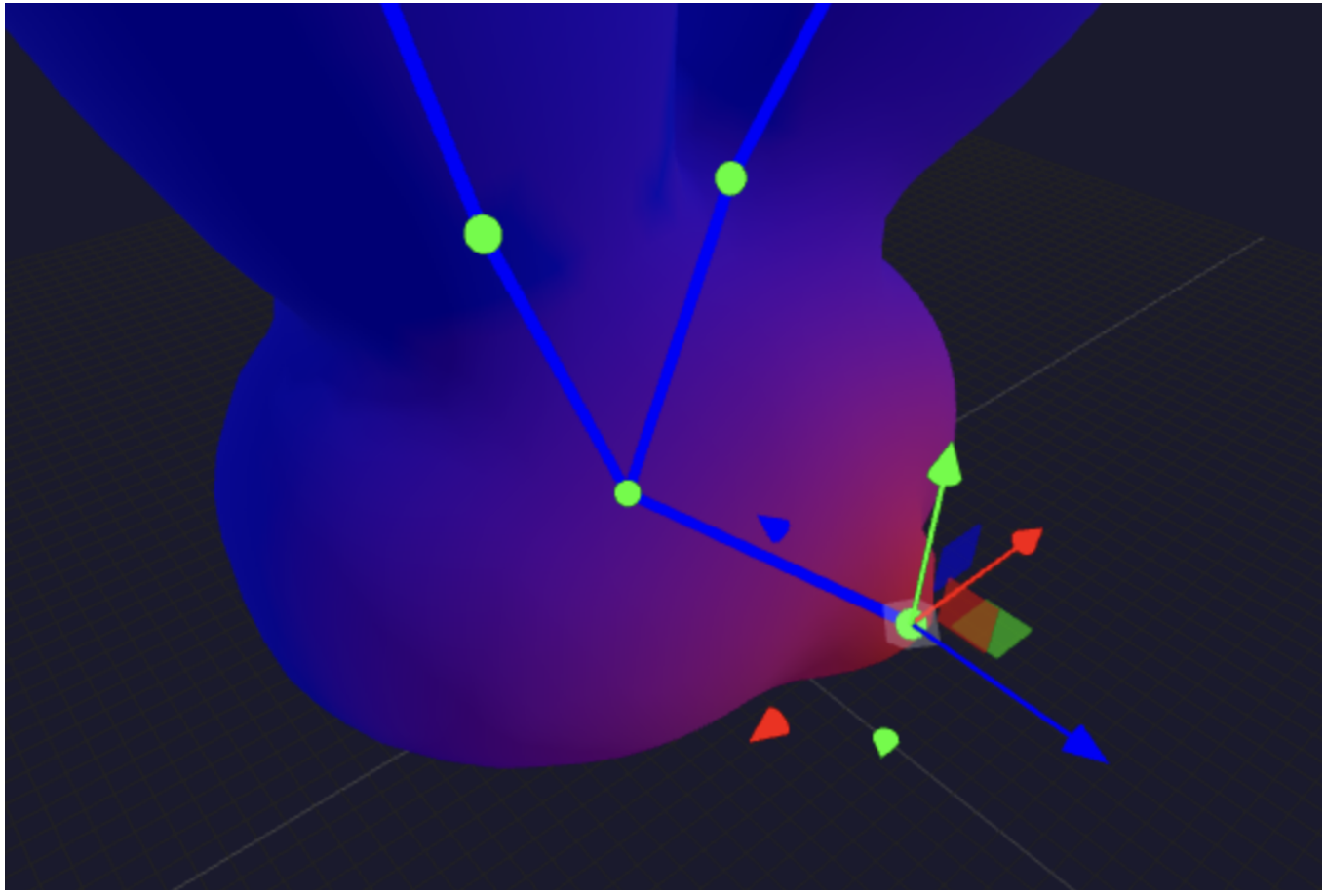


Merging: Snapping & Patching





Merging: Local Smoothing & Skin weight recomputation



Skeleton Refinement

The flow is simple and intuitive. The user can:

- **Collapse a bone**: 2 joints are merged into 1.
- **Split a bone**: A new joint appear at the middle of the bone.
- Extrude one joint from another joint.

Conclusion

Here is contribution of the work:

- Introduced a mesh cutting and stitching pipeline that preserves skeletal structure.
- Applied smoothing and diffusion to maintain geometric and skin weight continuity & coherence.
- Smartly locallize the region that requires complex computation.

Future Work

- Explore different Rigging algorithm (Dual-Quaternion Skinning, Direct Delta Mush)
- Explore different kernel to represent the length during isometric remeshing.
- Incorporate mesh subdivision and mesh simplification when the mesh is scaled

End of Presentation

Thank you for your attention!

References I

Chew, L. P. (1987).

Constrained delaunay triangulations.
In *Proceedings of the Third Annual Symposium on Computational Geometry*, SCG '87, page 215–222, New York, NY, USA. Association for Computing Machinery.

DOUGLAS, D. H. and PEUCKER, T. K. (1973).

Algorithms for the reduction of the number of points required to represent a digitized line or its caricature.
Cartographica, 10(2):112–122.

Nealen, A., Pett, J., Alexa, M., and Igarashi, T. (2009).

Gridmesh: Fast and high quality 2d mesh generation for interactive 3d shape modeling.
In *2009 IEEE International Conference on Shape Modeling and Applications*, pages 155–162.

Prasad, L. (2007).

Rectification of the chordal axis transform skeleton and criteria for shape decomposition.
Image and Vision Computing, 25(10):1557–1571.
Discrete Geometry for Computer Imagery 2005.

Sorkine, O. and Cohen-Or, D. (2004).

Least-squares meshes.
In *Proceedings Shape Modeling Applications, 2004.*, pages 191–199.