Automating the Artistic Workflow Regarding Skin Wrinkling in the Geometric Space

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Computer Graphics

Motivation

The workflow of character models controlled by a skeleton often ignores deformation, such as wrinkles. Such deformation is represented in the texturing stage (2D) before the animation. That leads to approximated and stationary baked textures instead of dynamic geometric changes. Here we created a tool that can generate wrinkles during animation while being easy to use in the existing pipeline.

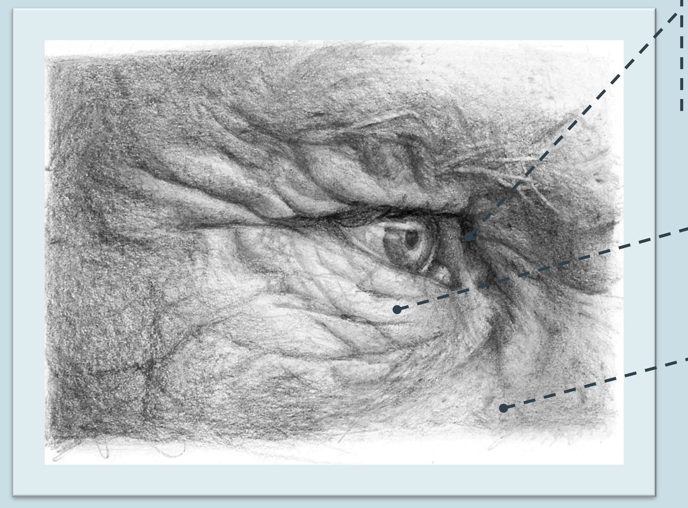
[left] Cameron, James. 2022. Avatar: The Way of Water. [right] Cameron, James. 2009. Avatar.

Empirical Observation

Why Skin Wrinkles Are a Complicated

Wrinkles are a section of skin with less support from underlying structures caused by biological components such as ligaments and collagen. The aspects of wrinkles we focus on are as follows:

- They are a comparatively **stationary portion** of the skin. As other parts of the skin are subject to displacement caused by stretching and compression, wrinkles tend to fall in the relative location forcing the surrounding skin to compensate.
- When a joint rotates to an angle less than the resting location, the skin will attempt to compress, but the **skin does not lose surface area** compared to a relaxed state.
- Wrinkling and **vertical displacement** help preserve the lower-bound surface area. [3]



Clark, Nolan (2017). *Eye with wrinkles study*

Artist Accessible Tool

1) Prioritize **aesthetics** over physics simulation
2) Require **minimum input** with easy to see results
3) **Fast algorithm**. Animation can range from 15-60 fps, the algorithm runs per-frame. (5 min - 4,500 - 18,000)

Methods

- Implement the tool in the industry standard 3D modeling software **Autodesk Maya (C++ API)**
- Write a data structure that references the nodes in the integrated data structure to traverse vertices outside of central vertices identified as a wrinkle vertex
- Extend the Dual Quaternion[1] skinning method and deform the submitted mesh after natural calculation

Algorithm

We will call this method **Mini Joint Rotation** on Contiguous Edges. We identify a "contiguous" edge set, an edge set that consecutively "points" in the same direction. We will take the generated position of some control algorithm[2] and rotate the vertex around the closest neighbor to the wrinkle by some degree of calculated compression, like a mini joint.

Then we will adjust the stretched vertices along the normal to reduce the stress between the moved and unmoved vertices, until an unmoved vertex is parallel to the axis of rotation. Then we will identify the most stretch point and translate all the moved vertices to reduce the stretch.

Complexity: O (n log n)

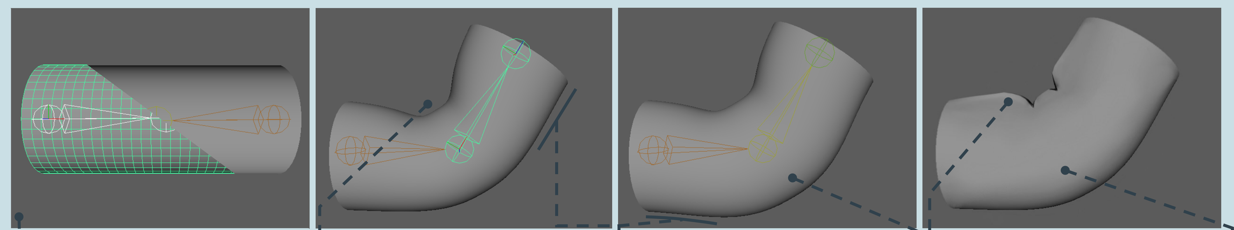
Analysis

Qualitative:

We assess the generated deformation based on the visual quality of the displacement location [1] and preservation of angles between vertices [3].

Quantitative:

Using a plugin from the Maya Marketplace, we calculate the volume and surface area of the mesh to assess the preservation of this aspect.



Algo- \ Rotation	**π/4** (45°)	**π/2** (90°)	**2** (120°)
Classic Linear	-0.0455	-0.1638	-0.2278
Dual Quaternions	0.0044	0.0082	0.0098
Mini Joint	0.0055	0.0062	0.0067

Volume (cm^3) difference ratio:

Volume growth is controlled by stretch reduction.

Algo- \ Rotation	**π/4** (45°)	**π/2** (90°)	**2** (120°)
Classic Linear	-0.0167	-0.0582	-0.0784
Dual Quaternions	0.0096	0.0334	0.0518
Mini Joint	0.0103	0.0138	0.0143

Surface Area (cm^2) difference ratio:

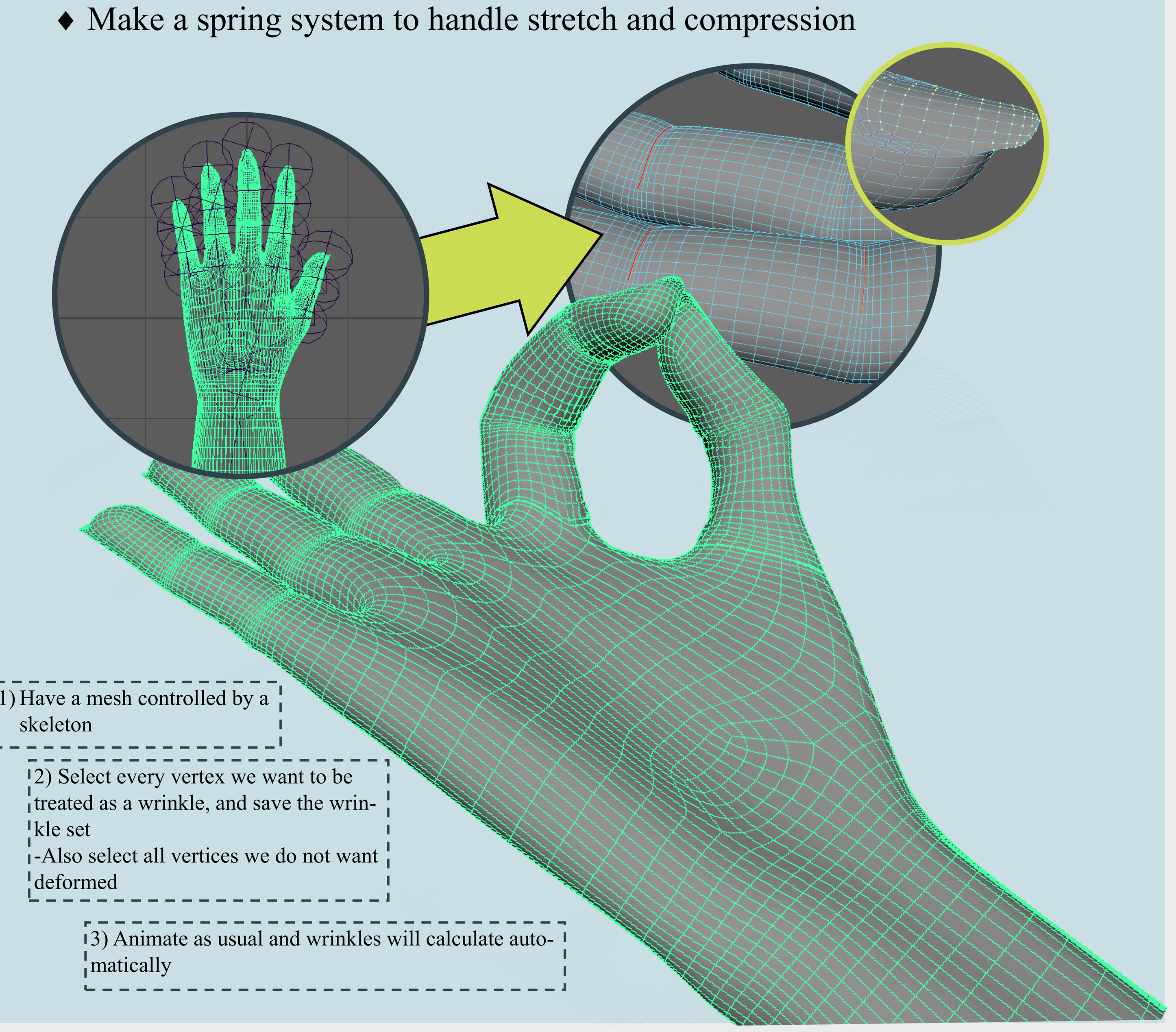
Same pattern the growth is limited.

Results & Future Work

The problem of wrinkles is complex as the reason for their occurrence is pure physics, which is often different in the artistic medium since the human body is very complicated, even when only referring to the epidermis.

We believe we made an algorithm that satisfyingly accomplishes these things. There may be some refinement of equations and potential development of other tools that this tool could rely on. We can then make some claims on future work.

- Add collision detection
- Develop a muscle system to work along with the skeletal animation
- Make a spring system to handle stretch and compression



References

[1] Caroline Larboulette, Marie-Paule Cani. Real-Time Dynamic Wrinkles. Computer Graph- ics International (CGI'04), Jun 2004, Crete, Greece. IEEE Computer Society Press, pp.522- 525, 2004, <http://www.computer.org/portal/web/csdl/doi/10.1109/CGI.2004.1309258>. <10.1109/CGI.2004.1309258>. <inria-00537455>

[2] Kavan, L., Collins, S., O'Sullivan, C., & Žára, J. (2006). Dual Quaternions for Rigid Transformation Blending.

[3] Yaron Lipman, Daniel Cohen-Or, Ran Gal, and David Levin. 2007. Volume and shape preservation via moving frame manipulation. ACM Trans. Graph. 26, 1 (January 2007), 5–es. https://doi.org/10.1145/1189762.1189767