Sculpt Processing for Character Rigging

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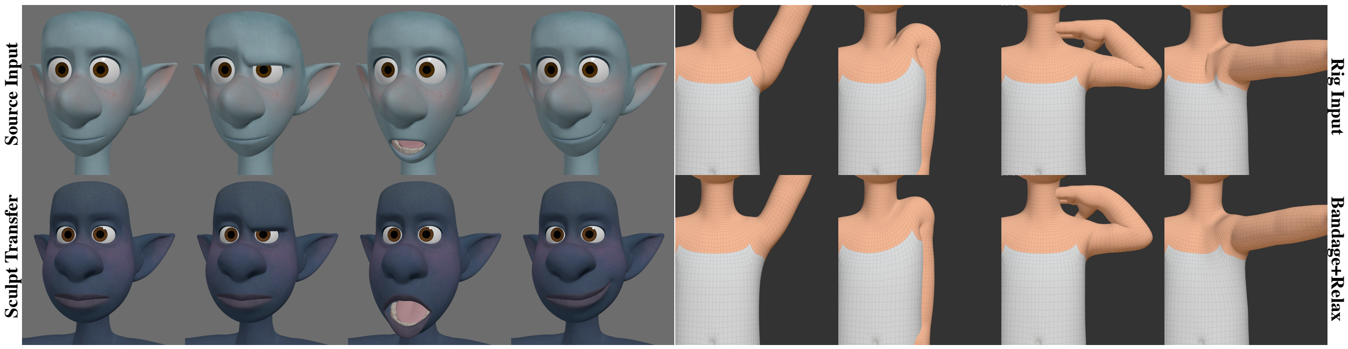

Figure 1: We present a set of geometric tools that assists the creation and reuse of sculpts between 3D characters. In the left, poses from one character (top) are transferred to another character (bottom), with rest shapes displayed in the left-most column. In the right, poses produced by a joint-based rig (top) are sculpted via our Bandage and relax tools (bottom). ©Disney/Pixar.

ABSTRACT

Pose-space sculpting is a key component in character rigging workflows used by digital artists to create shape corrections that fire on top of deformation rigs. However, hand-crafting sculpts one pose at a time is notoriously laborious, involving multiple cleanup passes as well as repetitive manual edits. In this work, we present a suite of geometric tools that have significantly sped up the generation and reuse of production-quality sculpts in character rigs at Pixar. These tools include a transfer technique that refits sculpts from one model to another, a surface reconstruction method that resolves entangled regions, and a relaxation scheme that restores surface details. Importantly, our approach allows riggers to focus their time on making creative sculpt edits to meet stylistic goals, thus enabling quicker turnarounds and larger design changes with a reduced impact on production. We showcase the results generated by our tools with examples from Pixar's feature films *Onward* and *Soul*.

ACM Reference Format:
Fernando de Goes, Patrick Coleman, Michael Comet, and Alonso Martinez. 2020. Sculpt Processing for Character Rigging. In *Special Interest Group on Computer Graphics and Interactive Techniques Conference Talks (SIGGRAPH '20 Talks), August 17, 2020.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3388767.3407377

1 INTRODUCTION

As feature animation productions scale in complexity, it is key to build power tools that leverage and share existing artistic work in order to automate repetitive processes and better support creative tasks. Towards this goal, we implemented a suite of sculpting tools that, used in conjunction, enables riggers to reuse and refine character poses produced by procedural rigs. Our toolset includes techniques to refit sculpts between different shapes (§2), cleanup rig artifacts (§3), and restore rest shape details (§4). These tools assume that character models are discretized by quad-dominant meshes with 3D vertex locations stacked column-wise in a matrix $\mathbf{X}$. We represent a slice of $\mathbf{X}$ with the vertex points incident to an individual face f by the matrix $\mathbf{X}_f$ and use $\mathrm{d}\mathbf{X}_f$ to indicate the matrix of edge vectors forming the boundary of f. We also denote by $\overline{\mathbf{X}}$ the rest points associated with a mesh pose $\mathbf{X}$ and then define a sculpt as the point differences required by a character rig to deform $\overline{\mathbf{X}}$ to $\mathbf{X}$. Lastly, we use $\mathbf{Y}$ instead of $\mathbf{X}$ to describe a source model with sculpts versus a target mesh to be sculpted.

2 SCULPT TRANSFER

Character rigs at Pixar are commonly structured with a set of sculpts covering various calisthenic poses. In previous shows, these pose-space sculpts were created repetitively for every single character, thus taking significant amount of time. In order to facilitate rigging setup, we developed a transfer tool that populates poses of a target character by refitting existing sculpts from a reference source model of different shape but sharing the same mesh connectivity. Similar to [Sumner and Popovic 2004], our approach first assigns a 3×3 matrix $\mathbf{F}_f$ to every mesh face f encoding the sculpts to be transferred between source and target models, and then generates a deformed pose $\mathbf{X}$ for the target mesh by minimizing a least-squares fitting term of the form $\sum_f \|\mathrm{d}\mathbf{X}_f - \mathbf{F}_f \mathrm{d}\overline{\mathbf{X}}_f\|^2$. While Sumner and Popovic [2004] extracts linear transformations using solely the rest $\overline{\mathbf{Y}}_f$ and sculpted $\mathbf{Y}_f$ poses of the source polygons, we propose instead to assemble face-based matrices $\mathbf{F}_f$ that account for the misalignment between source $\overline{\mathbf{Y}}_f$ and target $\overline{\mathbf{X}}_f$ rest shapes, in addition to the source deformation. To achieve this goal, we first compute the matrix $\overline{\mathbf{F}}_f$ mapping the source polygon from its rest to its sculpted

SIGGRAPH '20 Talks, August 17, 2020, Virtual Event, USA

ACM ISBN 978-1-4503-7971-7/20/08.
https://doi.org/10.1145/3388767.3407377

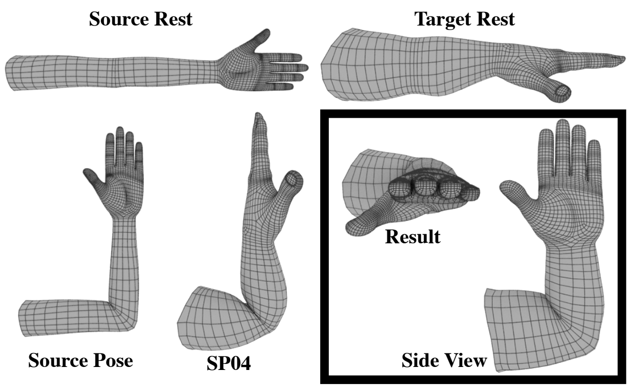

Figure 2: When source and target rest shapes have different orientations (top row), the method of Sumner and Popovic [2004] (SP04) leads to visual artifacts (left-bottom). In contrast, our transfer approach accounts for the rest shape misaligment and thus produces the expected result, as shown by the boxed images. ©Disney/Pixar.

shape so that $\|d\mathrm{Y}_f - \overline{\mathbf{F}}_f d\overline{\mathrm{Y}}_f\|^2$ is minimized. We then combine this transformation with the rotation matrix $\mathbf{R}_f$ that best aligns $d\overline{\mathbf{Y}}_f$ to $d\overline{\mathbf{X}}_f$, yielding the matrix $\mathbf{F}_f = \mathbf{R}_f \overline{\mathbf{F}}_f \mathbf{R}_f^t$. Geometrically, our construction of $\mathbf{F}_f$ first frames the target polygon to the rest shape of the source model via $\mathbf{R}_f^t$, transfers the sculpts $\overline{\mathbf{F}}_f$ from the source to the rotated target polygon, and finally rotates the stretched polygon back to the target space via $\mathbf{R}_f$. By aligning source and target polygons, our formulation refits the source sculpts to the shape of the target model agnostic to their world-space orientation, thus improving transfer results compared to prior work (Figure 2).

3 BANDAGE TOOL

When no reference sculpt is available to be transfer, sculpts need to be crafted manually for every relevant character pose. Since traditional character rigs using, e.g., joint transforms and skinning weights tend to produce visual artifacts, rigging artists often spend time cleaning up character poses produced by the deformation rig before being able to create any artistic edit. In order to reduce manual cleanup fixes, we implemented a shape reconstruction scheme, nicknamed the *Bandage* tool, that replaces entangled mesh regions with smooth surfaces. Our tool is similar to the method of Botsch and Kobbelt [2004], which generates 3D points $\mathbf{X}$ for user-selected mesh vertices by interpolating the positions of the remaining vertices. We compute this interpolation by minimizing the residual between the location of a selected vertex and the average of its adjacent vertices, subject to positional constraints at the unselected vertices. The objective function for this optimization can be concisely written as $\|\mathbf{L}\mathbf{X}^t\|^2$, where $\mathbf{L}$ indicates a mesh-based Laplacian matrix, thus leading to a linear solve with a bi-Laplacian matrix. We also considered variants using different powers of the Laplacian matrix, but the bi-Laplacian is the most used option. With our cleanup routine, we obtain smooth shapes ready to be sculpted.

4 REST-AWARE RELAXATION

So far we described how to reuse sculpts between different character assets (§2) and how to pre-process poses before sculpting (§3). We now present a post-processing tool that restores surface details from a reference shape onto a sculpted pose of the same 3D model. Our implementation follows the relaxation method of de Goes et al. [2018] using span-aware weights and rotated Laplacian coordinates. This approach is particularly well-suited for character sculpting since it recovers both the arrangement of edge spans designed by modeling and the rest space local features. It is worth noticing that this relaxation technique is complementary to the sculpt transfer detailed in §2, since the former involves only rest and deformed shapes of the same model, while the latter requires a pair of poses of a source model in addition to the target shape to be sculpted.

5 RESULTS

Our sculpt processing toolset was deployed as part of the rig authoring system in Presto. In the supplemental video, we include interactive sessions showcasing these tools. For the Bandage and the rest-aware relaxation tool, users select points associated with a sculpt, adjust parameters such as the number of relax iterations, and then compute deformations which are saved into the selected sculpt. Figure 1 (right) shows pose fixes automatically produced by these tools. For the sculpt transfer workflow, users load a reference character with the initial sculpt data, as well as the target model to which the sculpt should be transferred, and run the command that solves transferred sculpts as needed. Figure 1 (left) displays examples of poses transferred from a hero to a secondary character. As riggers gained experience with our sculpt processing tools, they have become an integrated part of rigging workflows. Riggers have reported a large amount of personal time savings, as they focus much less time on pose correctness and instead spend more time on style and art direction adjustments. In practice, we noticed that riggers tend to use the sculpt transfer tool to quickly get a plausible sculpt, and then combine the Bandage and relax tools with manual edits to achieve the final sculpt, as illustrated in Figure 3.

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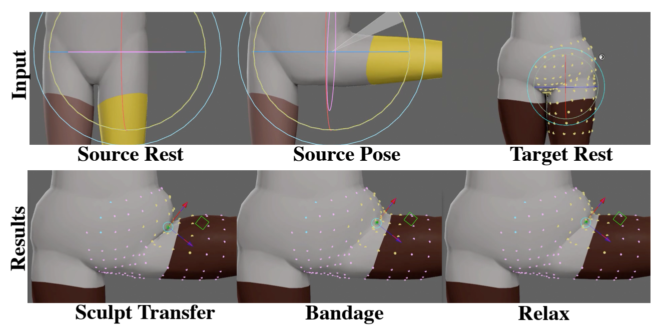

Figure 3: This example shows a combination of our sculpt processing tools. Starting from rest and posed shapes of a source model and a target mesh with the same connectivity (top-row), our transfer tool refits the source deformation as sculpts onto the target shape (bottom-left). In compressed areas, we refine our sculpts by cleaning them up using the Bandage tool (bottom-center) followed by our detail-aware relaxation (bottom-right). ©Disney/Pixar.