Space Rangers with Cornrows

Methods for Modeling Braids and Curls in Pixar's Groom Pipeline

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(a) Izzy Hawthorne **(b) Alisha Hawthrone**

Figure 1: Lightyear characters Izzy and Alisha Hawthorne and their respective grooms. ©Pixar.

ABSTRACT

This presentation is a debrief of the processes and methods added to Pixar's groom pipeline to create the hairstyles of Lightyear characters Alisha and Izzy Hawthorne. The processes include novel ways of generating braids, curls, braid partitioning hairs (edge hairs), and graphic shapes populated with hair.

KEYWORDS

Braids, Curls, Natural Hair, Groom Tools, Hair

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1 INTRODUCTION

Although braids are nothing new to the world, they are not commonly seen on animated human characters. The most popular braided hairstyles in animation are singular or doubled braids, few in count per style. However, in this presentation we will discuss the ways in which our industry can catch up to the real-world artistry and versatility of styled braids.

The tools used to create these hairstyles on Alisha and Izzy rely on source curves which are hand sculpted by groom artists. Patterns such as braids and curls are then generated and deformed along those source curves. These tools provide groom artists with enough proceduralism to skip the tedious process of sculpting complex patterns by hand while still preserving the need for artistic control and stylization.

2 BRAID CONSTRUCTION

The process of constructing braided hairstyles consists of two distinct parts. The first being the braids themselves, and second being the shape and direction of the hairs leading into the braids. In the making of both Alisha's and Izzy's hairstyles, we developed two methods to recreate these features.

2.1 Procedural Braids

We describe each strand of the braid with having the cross section of a lissajous curve, which is offset by the interval value between each of the N-strands. The distance between each knot of the braid depends on both the frequency value F as well as the number of control vertices N_{cv} and length of the source guide curve.

$$S(t) = \begin{cases} x(t) = A\sin(2\pi(F\alpha(t) + \delta)) \\ y(t) = B\sin(2\pi(F\beta(t) - \delta)) & t \in (0, 1) \\ z(t) += \omega \end{cases}$$

where:

A, B = Scalars for braid width and height at each cv
F = Frequency of knots
$\beta/\alpha = 0.50$
$\delta = i/N_{strands}, i \in (1, N_{strands})$
$\omega = Length/N_{cv}$

Each point of the lissajous cross section is then deformed along the source curve using orthonormal frames. These frames use the tangent segment at each cv to compute the normal and binormal. Once this frame is computed, artists can choose to orient the braid towards any axis. For cornrows, however, it is imperative for the braid to be aligned exactly with the scalp surface. Artists can choose to replace the cross-product normal with a scalp normal that is computed from the projection of a point along the source curve. This method works for cornrows specifically because we can assume that the source curves are close enough to the scalp surface to return a desirable projection point. The shape and properties of the braid can be artistically modified even further through root and tip amplitudes, tapering splines, scalp intersections, number of knots, and number of strands per braid.

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2.2 Creating Partitions between Braids

The accuracy of a braided hairstyle is just as dependent on the way the hair is partitioned as the braids themselves. To address this, we came up with a way to create natural looking edge hairs using the same source curves that are used for the braids. This tools take two or three curves as input: the first is the source, or the central curve, and the other one or two curves are the closest adjacent curves on either side. The tool produces a set of segments along the source curve, each of which is defaultly rooted at the midpoint of the segment between the source point and the nearest adjacent point. Artists can choose to mediate the length of these segments between the curves, or choose to use specific points along the source (or adjacent) curves as centroids for groups of segments. The resulting effect of these curves gives the illusion that the hairs are being pulled into the braid at each knot.

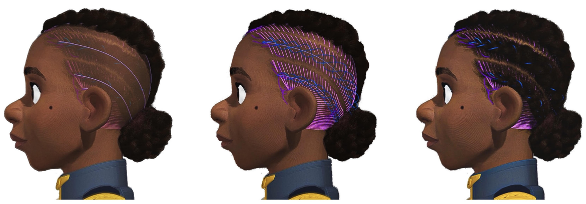

Figure 2: Process of creating braided and partitioning curves from hand-sculpted guide curves. ©Pixar.

3 EXPERIMENTAL CURL CONSTRUCTION

Previously at Pixar, natural and curly hair were mathematically defined by helices with perfect circular cross-sections supplemented with noise and other methods to acheive randomness. While this method can allow groom artists to create believable results for some hair types, it does not incorporate variable hair morpohology or consider multiple curl patterns. For Alisha's and Izzy's grooms, we explored new ways to style and generate natural hair that take these concepts into consideration.

3.1 Cross-Section Combinations

The objective of the curl tools created for Alisha and Izzy's grooms was to implement the idea that no two curls share identical morphology, even if they follow a similar pattern. We first define the hair type, which determines the average $frequency : amplitude$ ratio of the curls, and then we compute the list of possible cross-section shapes that will occur randomly throughout the curls. The algorithm begins with a dictionary of shape possibilites the artist wants to see in the results.

$CrossSections_{dict} =$

$$\begin{aligned} \{\, & 0 : \text{Lamé Curve} \\ & 1 : \text{N-Sided Polygon} \\ & 2 : \text{Ellipse} \\ & 3 : \text{Circle} \\ & 4 : \text{Polar Rose} \\ & ... : ... \\ & K : K_{th} \text{ Shape Possibility} \,\} \end{aligned} \tag{1}$$

The artist can then input the following variables:

U = uniformity of cross-section shapes along curl, $U \in (0, 1)$
$Shape_A$ = dominant cross-section shape
$R(A, F, P, O)$ = Range for randomization of curl parameters (below)

A = amplitude, F = frequency, P = phase shift, O = offset

The algorithm generates a 'shape list' where each shape included in the process reoccurs N number of times. The N value per shape is determined by its' tier: $Shapes_A$, $Shapes_B$, and $Shapes_C$. The secondary tier is determined by the desired hair type i.e. Types 2-4a/b/c. Using the Uniformity value U, we compute the respective probabilites of each tier where the probability of the primary shape is always U. For each iteration of a new curl, the shape list is randomly indexed into and returns the cross-section shape of that cycle at t where $t \in (0, 1)$

3.2 Curls with Graphic Shapes

Figure 3: Process of generating guides that form a sphere of curls. ©Pixar.

For Izzy's groom, we implemented a tool exclusively for her afro-puffs, which called for a very clean and spherical silouhette read. The tool generates N-rows and N-columns of curves that are rooted within a specific radius on the scalp. Each curve extends out to be on a surface defined by a perfect mathematical sphere. We then generate curls randomly rooted within the radius on the scalp and that follow the directionality of the sphere curves.

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