# Hair and Fur in an Evolving Pipeline


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**Figure 1: Furball use in production – *Captain Marvel* and *Rocket* in *Avengers: Endgame* (left, center) and huskies in *Togo* (right).**


## ABSTRACT

DNEG's in-house fur software, *Furball*, has been in continuous production use since 2012. During this time it has undergone significant evolution to adapt to the changing needs from production. We discuss how recent work on films such as *Avengers: Endgame* and *Togo* has led to a complete shift in the focus of our fur tools. This has helped us scale up to meet the requirements of ever more fur-intensive shows, while also opening up exciting opportunities for future development.



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## 1 INTRODUCTION

Hair is an essential component of many CG creatures. It is often an integral part of the character design, be it a signature hairstyle or the dense coat of a furry animal; it can also provide a near-invisible but crucial ingredient of the final shot, such as the vellus hairs used to add a subtle layer of photorealism to the otherwise smooth skin of a human *digi double*. As such, each show brings its own set of unique requirements.

DNEG's in-house fur system, *Furball* [Giordana et al. 2014], has been used in over 100 projects since its creation in 2012, and during that time it has weathered numerous changes in pipeline and artist workflows. So far, no single third party solution has been able to take its place and fully satisfy our production requirements. Key to *Furball*'s resilience has been its ability to evolve significantly in order to tackle issues of scale and realism in an evolving market.

## 2 FUR PIPELINE OVERVIEW

In recent years, DNEG's increased emphasis on creature work has led to the standardisation of the fur authoring pipeline. This now consists of 5 distinct stages.

- **Groom**: artists define the look of the hair and create a characteristic set of sparse "guide curves"
- **Rigging and animation**: motion and deformation are applied to the character's body.
- **Character effects (CFX)**: the motion is used to drive a "physics-inspired" simulation of the guide curves and their interaction with other parts of the character or scene.
- **Dense fur generation**: the motion of the guide curves is applied to the full dense groom.
- **Shading and rendering**: the final fur is rendered in situ on the moving character.

*Furball* started life as a grooming tool, based on the well-established *curve interpolation* technique. With this approach a node-based set-up, authored at the groom stage, is used to scatter hair follicles on a mesh, then shape the static dense groom. The same set-up is then used for procedural hair generation throughout the rest of the pipeline.

## 3 SCALING UP

### 3.1 Furry crowds

Some shows require us to produce large numbers of furry creatures. To deliver a hunting scene involving a herd of 300 bison in *Alpha*, *Furball* had to integrate with our crowd system. Crowd agents are represented procedurally in our pipeline, with the final deformation realised in the renderer. To avoid excessive cross-system integration, *Furball* had to be able to accept a geometry generated on the fly as an input to the procedural fur graph. The crowd agents also did not need a high level of detail, allowing the artist to make heavy use of parameters exposed in the *Furball* setup to provide in-renderer dynamic level-of-detail (LOD).



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*Furball* was originally developed as a hybrid GPU/CPU framework. During the asset development for *Alpha*, the GPU evaluation became too slow or unreliable for production use, mainly due to the asset size and the need for GPU-CPU data transfers. For this reason, we decided to retire the GPU acceleration and focus on a simpler, more efficient CPU implementation.

With these changes, *Furball* allowed us to deliver hundreds of bison in the initial hunting scene, without any perceptual differences between hero characters and their crowd versions.

### 3.2 Lifelike density

Other shows demand extremely dense fur: Disney's *Togo* features a sled team of 11 husky dogs, which required detailed digi doubles. The fur coat of a husky is made of two distinct layers – the dense undercoat provides insulation, while the thicker, straight guard hairs give the huskies their distinctive look. Our groom of a husky contained approximately 15 million hairs, organized into 13 separate fur systems (as compared to 600 thousand hairs on *Rocket* in *Avengers: Endgame*).

Instantiating 11 detailed dogs simultaneously in a scene proved challenging. The fur set-ups were slow to evaluate, and even the the hair in its raw representation took a significant portion of memory of a rendering blade. To address these issues, we improved the computation time of our set-ups, changed our evaluation model to minimise re-computation of each node, and implemented aggressive memory optimisation.

## 4 STYLE VS REALISM

### 4.1 Hyperrealism

Fast-paced action sequences in recent movies often make use of photorealistic *digi doubles*, performing actions that would otherwise be too dangerous or outright impossible for a real actor. Delivering a digi double can be a complex task, with different types of hair requiring bespoke approaches. For example, creating Captain Marvel's long hair required only around 150k individual hairs, but involved all stages of the pipeline, including complex physical simulation and interaction with the character's body and environment. Her vellus hair ("peach-fuzz"), on the other hand, had no need for physical simulation but was made up of nearly 1M very short hairs, despite being barely noticeable.

On Disney's *Togo* we needed to capture the specific light-scattering properties of the dogs' undercoat. Depending on the shot's requirements, we used two variants of hair shaders in our renders, a "physical" model and an "artistic" model: the "physical" model [Yan et al. 2015] approximates the structure of a hair, including its cuticle, cortex and medulla, using a statistical model with a limited number of physically-based parameters. This makes the rendered hair realistic from the onset, but limits the look to what is physically plausible. The "artistic" model, on the other hand, allows the user to adjust each hair lighting component separately, allowing much greater artistic freedom at the cost of a large number of parameters.

### 4.2 Hyper-stylisation

At the other end of the spectrum, characters in animated feature films tend to be highly stylised and typically rely on simple subdivision surfaces instead of heavy polygonal meshes. *Furball*'s built-in support for subdivision surfaces allowed it to accurately place the follicles on the limit surface without having to explicitly subdivide the cage mesh, which would result in additional memory usage.

## 5 AN EVOLVING MARKET

### 5.1 Working wih other studios

Whereas we would traditionally build and animate assets ourselves, in the case of *Rocket*, the client explicitly requested that we use a groom created by another studio. To support this workflow, we developed a number of *clustering* and *deformation* filters. Clustering filters analyse a static groom and detect its underlying structure, leading to a set of representative guide curves that are then deformed using a rig in animation or by simulation in CFX. Their motion is then propagated to the full groom using a set of deformation filters.

### 5.2 Third party solutions

This new deformation-based workflow has in turn led to a paradigm shift in the way we use our fur tools. Groom artists can now use any tool set to produce a static cache of the fur in the character's rest pose. The majority of them have chosen Houdini for this task, where the added flexibility allows for additional sculpting and detail, without any sacrifice in render, simulation or iteration times. The *Furball* setups used for deformation tend to be an order of magnitude smaller than the grooming set-ups, and as a consequence they are much faster to evaluate during renders, as well as easier to debug. Finally, since no hairs are generated during the deformation stage, we can guarantee hair counts are consistent between frames (this is a common problem with interpolative setups, compromising motion blur computation). By limiting the nodes used in *Furball*, we have also been able to focus our development efforts on improving render times.

### 5.3 Venturing into Feature Animation

The work done by ReDefine (DNEG's group of companies) on *100% Wolf* included 51 different furry characters, with several of them present in any given shot. The initial character design was created with *Furball*'s grooming toolset, and transitioned into the more efficient deformation-based framework after character development had been finalised. Our pipeline enabled this transition, and allowed the show to make heavy use of dynamic LODs and other render-time optimisations, which proved essential for the show's delivery.

## 6 MOVING FORWARD

With all these recent developments, *Furball* remains a crucial part of our hair and fur pipeline. The core technology fills a gap in our technology stack and adapts well to changing workflows and artist preferences. The change of focus over the last number of shows opens up new workflow and development possibilities, allowing us to tackle ever more challenging projects.

## REFERENCES

Francesco Giordana, Sarah Macdonald, and Gianluca Vatinno. 2014. Grooming a Lion for Hercules *(SIGGRAPH '14 Talks)*. ACM, Article 34.

Ling-Qi Yan, Chi-Wei Tseng, Henrik Wann Jensen, and Ravi Ramamoorthi. 2015. Physically-accurate fur reflectance: modeling, measurement and rendering. *ACM Transactions on Graphics (TOG)* 34, 6 (2015), 1–13.