WIP Paper: Applying Realistic Wing Animation and Modeling for Interactive VR Game Design

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***Abstract*—The domain of interactive game design has undergone significant advancements, increasingly prioritizing realism and immersive experiences. This work-in-progress paper delves into the crucial aspect of realistic wing animation and modeling in the context of interactive VR game design, inspired by a project centered around a game narrative involving "Feathermen". The focus lies on creating a comprehensive review of state-of-the-art techniques applied in modeling and animating wings for immersive gaming experiences and presenting our current work of developing a virtual reality (VR) game rooted in the narrative of "Feathermen", drawing inspiration from the stories centered on the Feather legend.**

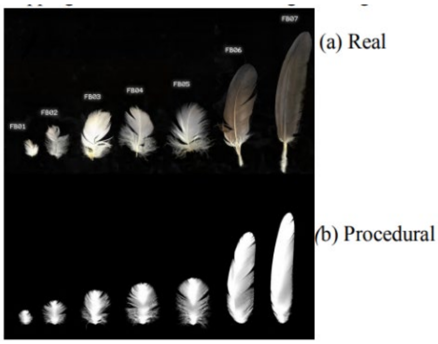
***Keywords*—Wing Animation, Feather Modeling, Virtual Reality, Game design**

I. Introduction

Interactive VR game design has witnessed significant advancements in recent years, with an increasing emphasis on realism and immersive experiences. In recent years, the field of interactive virtual reality (VR) game design has undergone remarkable progress, marked by notable advancements that have transformed the landscape of gaming experiences. One of the key trends driving this evolution is the heightened focus on realism [1] and the creation of truly immersive environments [2]. Developers are now leveraging cutting-edge technologies and innovative design approaches to simulate intricate details [3], lifelike graphics [4], and responsive interactions within virtual worlds [5]. This emphasis on realism not only enhances the visual quality of VR games but also strives to blur the lines between the virtual and real [6], enabling players to engage with the gaming environment in a more authentic and emotionally resonant manner [7]. As a result, players are increasingly drawn into VR games [8,9,10] that offer a heightened sense of presence, making the overall experience more compelling and captivating than ever before.

Within the context of our ongoing endeavor to construct a virtual reality (VR) game imbued with a narrative inspired by the enchanting world of "Featherman," a paramount facet influencing the immersive quality of gaming experiences resides in the meticulous animation and modeling of wings. This Work-In-Progress (WIP) paper undertakes the ambitious task of presenting a thorough and comprehensive review of contemporary techniques at the forefront of the application of realistic wing animation and modeling within the realm of interactive game design. Acknowledging the pivotal role that wings play, particularly in genres like fantasy and simulation, we delve into the current landscape of methodologies employed to breathe life into these fantastical appendages. As we explore the cutting-edge advancements in the field, our focus remains on elucidating the strategies employed to integrate lifelike wing movements and feather detailing into fabric of virtual worlds. Simultaneously, this paper serves as a platform to showcase our ongoing work—a virtual reality game intricately woven with narrative threads of "Feathermen." Drawing inspiration from ancient fantasy tales steeped in legend of feathers, our immersive VR game aims to push the boundaries of storytelling and technological innovation, promising a captivating experience for players by embracing rich tapestry of fantasy narratives and potential of advanced interactive technologies.

At the heart of our gaming narrative unfolds a rich and expansive continent, a fantastical realm teeming with a diverse array of inhabitants ranging from enchanting mermaids to resilient dwarfs, fierce barbarians, and the extraordinary Feathermen—humanoids bestowed with the ethereal gift of feathered wings that grant them the extraordinary ability of flight. Within this intricately crafted world, the delicate balance is disrupted as conflicts erupt, and the tranquility of the Feathermen's village is shattered by relentless barbarian invasions. The gameplay experience immerses players into the intense and strategic role of a guardian perched atop a majestic tree, armed with a bow and a resolute determination to thwart the marauding hordes of barbarians. The dynamic and evolving storyline unfolds through the player's perspective as they navigate the challenges of defending against these invasions, engaging in thrilling encounters that test both their marksmanship and tactical prowess. As a visual precursor to the immersive journey that awaits, a captivating trailer has been



(a) Real scanned feathers (a) and their procedurally generated copies (b).

(b) Application of the blended guide meshes method.

Figure 1. Feather grooming using blended weighting function[11]

meticulously crafted, offering a tantalizing glimpse into the intricate storyline, captivating characters, and key highlights that define this unique gaming experience. The trailer serves as a portal into the world we've painstakingly built—a world where fantasy, strategy, and the allure of flight converge, promising players an unforgettable and visually stunning adventure that transcends the boundaries of traditional gaming narratives.

At the core of both the gaming experience and the narrative intricacies lies the pivotal element of feathered wings, an aspect demanding meticulous attention to precise modeling and animation for an authentic and immersive encounter. This comprehensive study undertakes a dual-pronged exploration, firstly delving into an exhaustive review and summation of the contemporary landscape of realistic wing animation development within the gaming sphere. Unraveling the intricacies of this evolving field, the examination spans methodologies, innovations, and technological breakthroughs that shape the lifelike animation of wings in virtual environments. As the study traverses this expansive terrain, it meticulously distills the state-of-the-art techniques that have emerged as benchmarks in the industry. Building upon this foundation, the focus then shifts to the distinctive realm of the Feathermen, a humanoid race blessed with feathered wings that become the centerpiece of their identity and prowess.

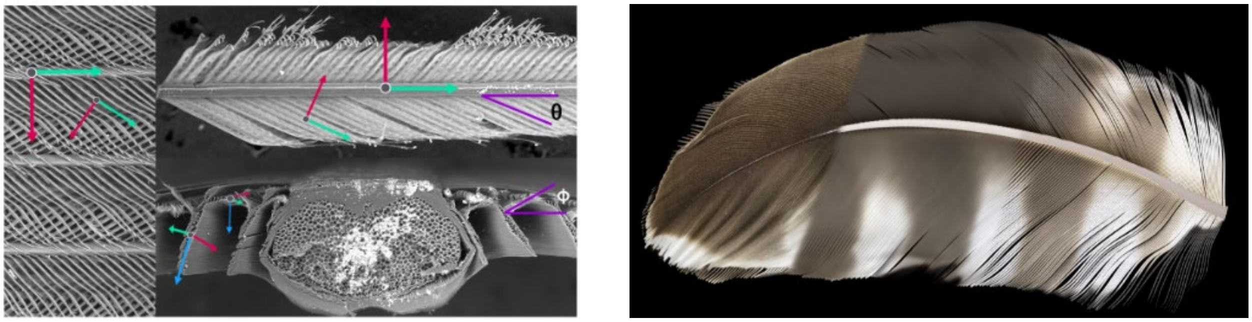
With a nuanced understanding of the selected techniques gleaned from the comprehensive review, the study transitions into the application phase. Herein, the feathered wings of the Feathermen are brought to life through an intricate fusion of modeling and animation techniques, specifically tailored to encapsulate the ethereal and dynamic nature inherent in these fantastical appendages. This dual-stage exploration not only serves to elucidate the advancements within the broader field of realistic wing animation but also establishes a tailored framework for bringing the unique Feathermen's wing movement to the forefront of the gaming narrative, thereby contributing to the ever-evolving tapestry of interactive storytelling and virtual world creation.

II. Background and Related Work

Within the realms of feathered wing modeling, the existing body of literature, albeit limited, constitutes a specialized and intricate domain predominantly centered on three key facets: feather rendering, meticulous feather modeling, and shading. The literature delves into these aspects with a remarkable emphasis on detailed and sophisticated methodologies, illustrating a commitment to capturing the nuanced intricacies of avian plumage within virtual environments. Augello et al. (2019)[17] have notably contributed to this discourse by synthesizing a comprehensive approach to emulate the complex movements inherent in bird wing feather dynamics. The three fundamental steps outlined by Augello et al.—grooming, lamination, and art-directed motion—serve as a roadmap to achieve a realistic and visually compelling simulation. Grooming involves the careful arrangement and alignment of feathers, meticulously replicating the natural order observed in avian species. Lamination, on the other hand, deals with the layering and integration of feathers to evoke a realistic visual effect, ensuring a seamless blend of individual feathers into a cohesive whole. The final step, art-directed motion, introduces a dynamic dimension to the model by intentionally animating feathers to mirror the organic and intricate movements of a bird's wing. This tripartite approach, underpinned by advanced computational technology, facilitates the successful simulation of tens of large wing and tail feathers, along with thousands of body feathers. The culmination of these techniques represents a significant leap forward in the realm of feathered wing modeling, showcasing a sophisticated fusion of scientific precision and artistic finesse that pushes the boundaries of what can be achieved through the virtual representation of intricate biological structures.

A. Feather Grooming

Among various grooming methods, Seddon et al. (2008) [11] proposed a unique method by creating groomed feathers that are then blended by painting a weighting function onto a base mesh, which gives a continuous variation in the groom across the bird’s body. They started by selecting a number of key feathers, then recreated with a procedural feather grooming system to



(a) SEM images of interlocking barbs (left), a single barb (top), and shaft and barb cross sections (bottom).

(b) Different modeling approach

Figure 2. Feather grooming using substructure-based shading approach[12]

match the appearance using a Renderman DSO as shown in Figure 2. Another pivotal paper explores rendering techniques for feathers in computer graphics, emphasizing the inadequacy of traditional models, and proposes a substructure-based shading approach [12]. This technique aims to capture intricate light interactions within feathers by incorporating substructures' reflectance, thus significantly enhancing the fidelity of rendered appearances compared to conventional methods.

Traditionally, feather modeling has relied on simplified curve structures or borrowed bidirectional curve scattering distribution functions (BCSDFs) from hair models, which fail to accurately represent the intricate light interactions within feathers. This work advocates for a specialized rendering model tailored specifically to the multi-scale assembly found in feathers. By leveraging scanning electron microscopy (SEM) imaging and controlled photography of feather specimens, the study emphasizes the importance of substructure-based shading calculations for a more accurate representation of feathers' appearance as shown in Figure 3 (a). Figure 3 (b) shows feather grooming modeled by different approaches. The left portion shows an osprey feather photographed. Then the middle portion shows feathers that are modeled as curves and rendered as hair. The right portion shows simulated microstructures using the proposed shading technique. Noted that variation in specularity exhibited by microstructures in photograph that the proposed technique captures in comparison with hair-fiber approach.

Existing feather modeling techniques in computer graphics often limit their representation to the barb level and commonly render feathers as hair fibers with simplistic scattering functions. The research challenges these methods by proposing a substructure-based shading technique, aiming to simulate the light interactions from barbules and rami. This new approach involves incorporating substructures' reflectance within a simplified cylindrical representation of the feathers, significantly enhancing the fidelity of rendered appearances compared to traditional hair-based approaches. The study employs RenderMan, utilizing PxrHair variations, and demonstrates visually superior results in rendering feathers by capturing the specular variations present in original photographs.

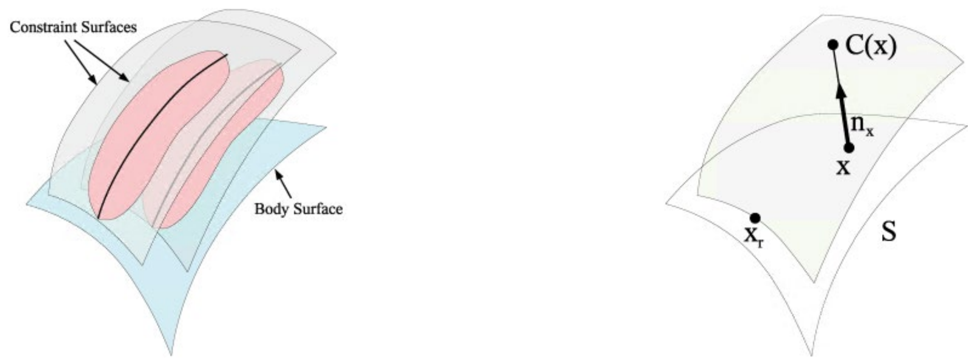
The research underscores the significance of accounting for substructures in feather rendering for achieving photorealistic results. While the proposed method shows promising advancements, future work aims for more sophisticated models that match the intricate shapes of feather components, improvements in scattering distribution terms, and integrating wave-optics models to further enhance the accuracy of rendered feather appearances. This study marks a foundational step in developing comprehensive rendering models capture intricate light interactions within feathers, laying groundwork for more realistic representations in computer-generated imagery.

B. *Feather Lamination*

Once the grooming feather characteristics are ready, the next question comes to the feather covering. A brief summary is provided in Table 1, and the current widely used methodology is proposed by Weber et. al. (2009) using the implicit constraint surfaces method. The method proposed by

Table 1. Information on video and audio files that can accompany a manuscript submission.

Study	Summary
Kaufman and Chen[13]	1. Offsets were calculated for every control point of a feather. 2. May minimize grooms' interpenetration, but cannot fix all
Robertson and Aitken[14]	1. Ignore geometric interpenetration altogether and simply use a variant of the painter's algorithm
Fordham[15]	1. Process feathers from tail to head using rigid body deformation. 2. But may has frame coherency nd volume inflation problems (Aitken et al. 2004)
Weber and Gornowicz[16]	3. Implicit constraint surfaces method



(a) Feather constraint surface example (b) Constraint surface definition

Figure 4. Implicit constraint surfaces method

Weber et. al. (2009)[16] first defines an implicit surface that is associated with a unique potential field value anchored to the skin of the character, which is referred to a constraint surface. Then, the constraint surfaces are implicit functions defined as a displacement from the character skin surface and are guaranteed by construction to avoid intersection with any other constraint surfaces as shown in Figure 4

C. Art-directed Motion Methodology

Art-directed technology is commonly used in CG films. It is very powerful to talk about a sequence in terms of its biology and its "anatomy"9. In terms of feather wing animation, it is recommended to consider the environmental effect on the feather itself, for example, wind. It is recommended to use 3-D procedural noise fields such as Perlin noise or Wavelet noise8 to drive the rotation values of the feathers.

Other considerations may include the secondary motion of the feather. For example, Hieronymus20 uses dissection and histology to identify previously overlooked interconnections between musculoskeletal elements and feathers in rock pigeons. Sometimes, performing a full feather mesh physical simulation for secondary motion can be prohibitive. Therefore, Augello et al.[17] tracked the root points of the feathers per frame in a shot. Overall, this technology is not directly related to detailed feather generation and animation but uses commonly incorporated filming techniques in most CG animation films to improve overall performance of feather movement simulation.

Augello et al. (2019) [17] combined the aforementioned grooming and lamination techniques[11, 16, 18], and then extended the study using the art-directed motion methodology including wind, secondary motion, finagling, and other special effects. They provide an in-depth exploration of the hummingbird system, a groundbreaking advancement in bird feather simulation and animation. The comprehensive discussion encompasses various crucial aspects of feather manipulation in digital environments. Beginning with feather modeling and grooming, the article outlines an innovative procedural technique involving interactive feather grooming, uniform distribution of follicles based on painted density, and attribute manipulation for size, direction, and overlap reduction. Additionally, the article introduces the concept of "Lamination," aimed at avoiding feather intersections within wing surfaces and skin, albeit with certain limitations in highly concave surfaces. Furthermore, the work delves into art-directed motion effects, where wind simulation and secondary motion are integrated to produce realistic feather movements, complemented by special effects such as ruffling and puffing.

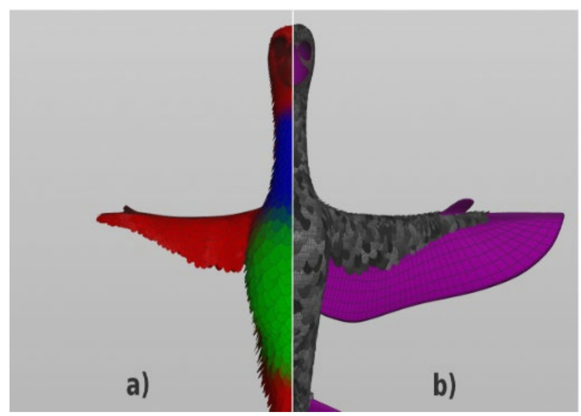


Figure 3. a) Initially instanced feather meshes, and b) Laminated feather meshes viewed along with driver surface. (implicit constraint method by Augello et al. 2019)[17]

The implementation of this cutting-edge system is a node-based procedural third-party package showcasing its real-time interactive grooming capabilities and frame-independent lamination processes, enhancing the efficiency and visualization of feather meshes. Its successful application in DreamWorks productions for grooming a vast number of feathers on numerous birds, along with its utility for both hero shots involving art-directed motion and automated batch

Figure 5. Feathers created using Hummingbirds (Augello et al., 2019)[17]

lamination for the majority of shots, demonstrates its significant impact on advancing feather simulation and animation techniques in the realm of film and visual effects.

III. Current Study and Result

Given the VR game story background of “Feathermen”, in the immersive gaming experience of this captivating adventure, players find themselves at the epicenter of a riveting clash between two distinct races—the noble Featherman and the fierce Barbarians. As shown in Figure 7, the stage is set for an intense confrontation where Barbarians, armed with menacing axes, charge forth relentlessly from every conceivable direction. As the protagonist, players wield a powerful bow and a quiver of arrows in their left hand, ready to unleash precision and skill against the encroaching threat. The seamless integration of virtual reality mechanics allows players to exercise precise control over arrow shooting, utilizing the right-hand controller to aim and release their shots with unparalleled accuracy. This dynamic scenario not only tests the player's strategic prowess but also immerses them in a visually stunning and action-packed world where the fate of the Featherman civilization hangs in the balance.

In the modeling process, the character prefab "Erica" was sourced from Mixamo. Initially, attempts were made to simulate feathered wings using two opposing 3D object planes adjusted to appropriate sizes and layered with wing picture albedo modified via Photoshop. The wing and incorporation method is developed by the author herself. Although this method successfully created basic wing objects linked as child objects to the character Erica. The challenges arose during flight scenes where the wing movement failed to synchronize with the character's speed, resulting in a disconnect between wing and body movements, particularly at higher speeds, as shown in Figure 8 (a).

The second practice incorporates a public Phoenix wing prefab from the Unity Asset Store. This prefab was created using the methodology workflow mentioned in section 2, and it is incorporated into this gaming character like the previous wing, which was based on a plane model. To better incorporate the module into this study, the wing's color was modified based on storyline by Photoshop. Afterward, this prefab was incorporated into the game as child object of character Erica to create realistic fluttering animations as depicted in Figure 8 (b).

As shown in Figure 9, the feathered wing is successfully attached to Erica and the flapping is smooth and clear. However, the animation and movement of the current wing are predetermined by prefab’s author, and it is hard to change and react based on the character’s movement. Therefore, a comprehensive review is conducted in this study to investigate the possible reproduction of the feathered wing’s animation and flapping movement.

In this game design scenario, as shown in Figure 9 (a), Erika takes center stage with a unique and innovative twist—her character is adorned with wings, affording her the remarkable ability to unleash a barrage of arrows while maintaining a stationary position. As the game unfolds, the virtual village comes to life with the instantiation of 20 identical characters at its inception, each embodying the role of skilled archers poised for battle. Positioned on the battlefield against the relentless Barbarian onslaught, the archers collectively rain arrows upon the enemy, heightening the intensity of the warfare. As shown in Figure 9 (b), the captivating detail of this virtual spectacle is accentuated by the continuous flapping of the archers' wings, synchronizing with the rhythmic release of arrows and creating a mesmerizing visual and auditory experience that truly immerses players in the heart of the virtual conflict.

As shown in Figure 10, a player is playing our VR game of “Featherman”. The feathered wing is successfully attached to Erica and the flapping is smooth and clear. However, the animation and movement of the current wing are provided by the prefab maker, it is hard to change and react based on the character’s movement. Therefore, a comprehensive review is conducted in this study to investigate the possible reproduction of the feathered wing’s animation and flapping movement. Experiment result’s video recording can be found through this URL link: https://youtu.be/0wq-bXq2VGg

IV. Conclusion

In this work-in-progress paper, the focal point lies in underscoring the pivotal significance of substructure-based shading techniques in the rendering of feather appearances, a

Figure 7. “Feathermen” VR Game Story Introduction

(a) Method 1-using two opposing 3D object planes to develop feathered wings.

(b) Method 2-using phoenix wing prefab on the Unity Asset Store

Figure 8. Feather wing design methods in this study

(a) Attaching phoenix wing prefab on character.

(b) Realistic wing animation in Unity.

Figure 9. Feather wing development example in this study

key element for attaining photorealistic results. The methods proposed in this study showcase promising strides in this direction, but ongoing efforts are directed toward refining existing models, enhancing scattering distribution terms, and incorporating wave-optics models. These refinements aim to push the boundaries of accuracy in simulating intricate light interactions within feathers. As a collective pursuit, this research marks a foundational step towards the development of rendering models that authentically capture the nuanced play of light within feathers, promising a future where computer-generated imagery attains unprecedented levels of realism. This ongoing exploration is poised to unlock new frontiers in the realm of visual representation, offering a profound contribution to the field of computer graphics.

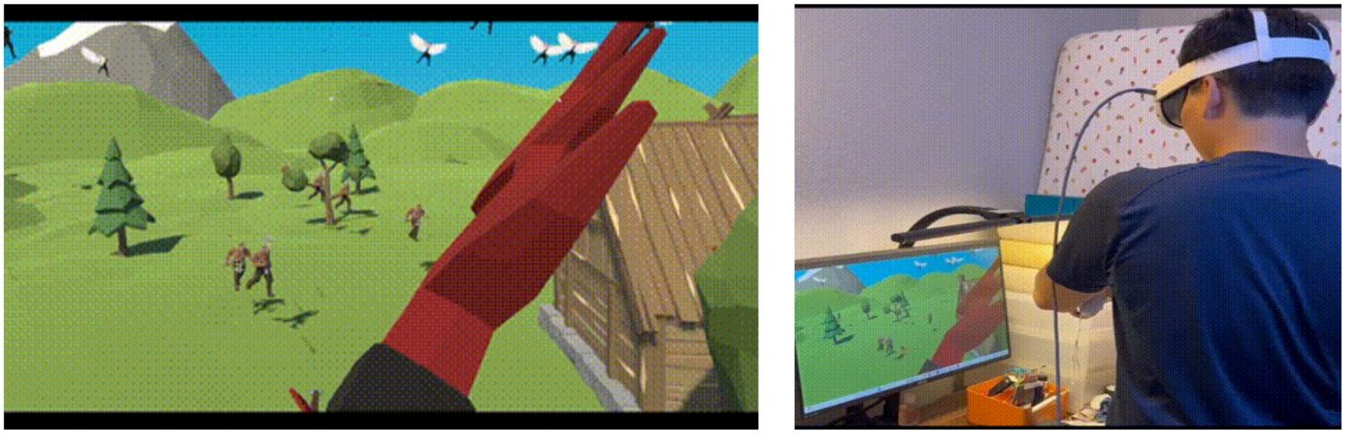


Figure 10. “Featherman” game view in VR.

Future Work. Building upon the foundation laid by the exploration of feathered wings in interactive game design, potential future studies are summarized in this section: Firstly, the wave-optics integration for photorealistic rendering should be further investigated. Extending the current rendering models to include wave-optics principles would be a significant leap forward in achieving photorealistic feather rendering. Integrating wave-optics models could accurately capture complex light interactions within feathers, allowing for a more faithful representation of specular variations and structural coloration. Secondly, more research can be focused on interactive feather grooming techniques. Investigating interactive feather grooming techniques akin to the Hummingbird system's procedural groomin g capabilities could enhance efficiency in feather manipulation. Future studies could explore real-time grooming tools, enabling artists to interactively modify and manipulate feather attributes for more precise control and realistic feather behavior in games.

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