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"CT2Hair: High-Fidelity 3D Hair Modeling using Computed Tomography"

With the increased popularity of video games and social media, the need for creating realistic digital humans has grown significantly. Hair is a vital aspect of representing a human digitally, yet creating accurate digital hair models is particularly challenging due to the large number of strands and the incredible diversity in styles and types of hair.

Traditionally, 3D hair models were manually created by artists. This process, while effective, is time-consuming, difficult to scale, and limited by the artists' tools. Image-based hair reconstruction methods have since emerged, providing higher-quality results with less effort. However, these methods suffer from occlusion, meaning that the interior of the hair cannot be observed. Missing regions must be filled in, which limits the accuracy of the models, particularly for complex hairstyles like very curly hair. Additionally, these methods often fall short in applications such as animation.

The study "CT2Hair: High-Fidelity 3D Hair Modeling using Computed Tomography" presents a new method for digitally reconstructing hair strands using wigs made out of real human hair. This process employs computed tomography (CT), which uses X-rays to generate density volumes of hair regions. While CT has been previously utilized in computer graphics applications, this study is the first to apply it to hair modeling. CT allows researchers to visualize the entire hair structure, not just its visible surface. This method follows a coarse-to-fine approach: guide strands are created from CT data, dense strands are interpolated using neural techniques, and the final model is refined to conform to the density volume.

To begin, the wigs are scanned using a CT scanner to produce 3D density volumes. The resolution of these volumes depends on the scanner's hardware and the wig's size. The initial scans were noisy and blurry due to the scanner's Modulation Transfer Function (MTF), which blurs the output, and the low radiodensity of hair, which provides low contrast against air. To address these issues, researchers manually set thresholds to filter out irrelevant data, such as air and the mannequin head. Removing the wig's underlying hair net required a more complex approach: the strand roots were segmented using a higher density threshold, point normals were estimated from the bounding sphere center, and the surface was reconstructed. Voxels near the reconstructed surface were then deleted to eliminate the hair net.

After preprocessing was complete, a 3D orientation field was computed from the 3D density volume. Traditional kernel filtering methods performed poorly on this study's noisy and blurry data, so the researchers developed a vector calculus-based method to estimate orientations accurately. Each voxel was treated as a 3D point, and a point cloud of the hair wig was generated. Short hair segments (or partially connected hair strands) were first generated by connecting neighboring points along their orientations to create a dense point cloud. This cloud was then cleaned using mean-shift point cloud filtering to remove noise. These short hair segments were connected and extended to form complete hair strands, though they were initially incomplete and distant from the scalp due to noise introduced by the hair net. The hair segments were clustered into two sets: complete fine strands and isolated poor segments. Poor segments were redirected and grown alongside their nearest fine hair strands, and the union of these sets formed the guide hair strand set attached to the scalp.

The guide strands were subsequently interpolated to achieve uniform distribution across the scalp, and dense strands were optimized using the source density volume as a target. This optimization significantly enhanced realism, creating natural wisps and improving the overall visual quality.

This study marks the first successful recovery of occluded hair structures in a scalable and unified framework capable of handling diverse hair types. The researchers demonstrated that their gradient-based orientation method outperformed previous approaches by producing more continuous and less noisy orientations. However, this method has limitations and cannot be applied to humans due to the high radiation levels required for CT scanning. Nonetheless, the advancements in this study pave the way for future developments in 3D hair modelings, offering a scalable and accurate solution for digital hair reconstruction.