Muscle-Based Facial Retargeting with Anatomical Constraints

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Figure 1: We first run an actor muscle simulation targeting the facial shape obtained through performance capture (Far Left) to obtain a simulated shape (Middle Left). The actor muscles are then retargeted onto the creature using the approach of [Cong et al. 2016] (Middle Right) and our approach which incorporates additional anatomical constraints (Far Right). The addition of our novel anatomical constraints corrects the diagonally upwards creases on the upper lip and the horizontal crease interior to the upper red lip margin while accentuating the lip roll to better match the original actor shape. ©2019 Marvel Studios. Used with permission. All rights reserved.

ABSTRACT

We present a physically based facial retargeting algorithm that is suitable for use in high-end production. Given an actor's facial performance, we first run a targeted muscle simulation on the actor in order to determine the actor blendshape muscles that best match the performance. The deformation of the actor blendshape muscles are then transferred onto the creature to obtain the corresponding creature blendshape muscles. Finally, the resulting creature blendshape muscles are used to drive a creature muscle simulation which yields the retargeted performance. In order to ensure the anatomically correct placement of the muscles, cranium, and jaw, we introduce novel anatomically motivated constraints during the transfer process. Compared to previous approaches, these constraints not only improve the expressiveness of the retargeted creature performance to the actor performance but also eliminate spurious visual artifacts.

CCS CONCEPTS

• **Computing methodologies → Physical simulation**; *Animation*; Computer graphics.

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KEYWORDS

facial animation, retargeting, muscles

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1 INTRODUCTION

Recent advances in muscle simulation for facial animation [Cong et al. 2015, 2016] have led to its use at Industrial Light & Magic for improving the anatomical validity of keyframe animated creatures [Cong et al. 2017; Lan et al. 2017]. Inspired by the success of their approach, we pursued the use of facial muscles as an anatomically motivated basis for retargeting in high-end film production. However, we found that the retargeting approach of [Cong et al. 2016] often resulted in retargeted creature performances that were both less expressive and contained more spurious visual artifacts compared to those obtained from applying traditional geometric approaches to the face surface.

We postulate that these problems arise because [Cong et al. 2016] transfers the deformation of each muscle independently. In reality, the fibers associated with different facial muscles are interwoven in many regions of the face effectively coupling the motion of different muscles together by enforcing positional constraints between them. Transferring the deformation of each muscle independently allows muscles to move apart at common insertion points (e.g. the modiolus at each corner of the mouth), lift away from their origin points on the cranium and jaw, and pass through each other bringing a deep muscle being closer to the surface of the face than a superficial muscle. These errors lead to a non-physical cancellation and accumulation of forces in the subsequent creature muscle simulation resulting in loss of expressiveness and spurious visual artifacts. Our retargeting approach fixes these problems by enforcing anatomically correct positional constraints between the muscles and transferring the deformation of all of the muscles at once. This results in a retargeted creature performance that is more faithful to the actor performance while also eliminating the aforementioned spurious visual artifacts.

2 SIMULATION FRAMEWORK

Given a high-resolution face mesh of the actor in the neutral pose, we construct a simulatable anatomical face model for the actor by morphing from a high-fidelity template model [Cong et al. 2015, 2017; Lan et al. 2017]. In addition, we skin the high-resolution face mesh to the cranium and jaw and propagate the skinning weights to the muscle volumes and surfaces using Poisson interpolation. This process is repeated for the creature using the same template model which results in a straightforward one-to-one correspondence between the muscle surfaces of the actor and creature. Furthermore, the creature muscle volumes are barycentrically embedded in a background tetrahedralized volume. This background volume is constructed by discarding the tetrahedra in the creature's tetrahedralized flesh mesh that do not intersect any muscles.

3 RETARGETING WITH ANATOMICAL CONSTRAINTS

Given an actor facial shape, we use the art-directed quasistatic muscle simulation framework of [Cong et al. 2016] in order to compute actor muscle tracks (consisting of a deformed tetrahedralized volume and triangulated surface) that drive the muscle simulation to closely match the facial shape. An actor facial shape and the corresponding targeted muscle simulation are shown in Figure 1 Far Left and Middle Left respectively. Our retargeting algorithm starts by inverse skinning these muscle tracks to the neutral cranium and jaw configuration in order to reduce errors due to linearized jaw rotations. Then, we apply deformation transfer [Botsch et al. 2006; Sumner and Popović 2004] to map the deformation of the actor's muscle triangulated surfaces onto the creature's muscle triangulated surfaces. Finally, the morphing algorithm of [Cong et al. 2015] is used to morph the creature muscle tetrahedralized volumes using the displacements of the corresponding creature muscle triangulated surfaces as Dirichlet boundary conditions.

At this point, one could follow the approach of [Cong et al. 2016] and optimize for the rigid degrees of freedom that yield the most anatomically valid relative placement of the resulting creature muscle tracks as a postprocess. However, this would still yield muscle volumes with inaccurate insertions because the rigid degrees of freedom cannot represent the shape changes in one muscle due to another adjacent/overlapping muscle. See Figure 2 Left. Thus, we need to enforce constraints between the muscles during deformation transfer. To do this, we map the deformation of the creature muscle volumes onto the background tetrahedralized volume again using deformation transfer with each background tetrahedron's deformation is driven by all of the muscle tetrahedra which intersect it. In order to determine the remaining global translation, we average

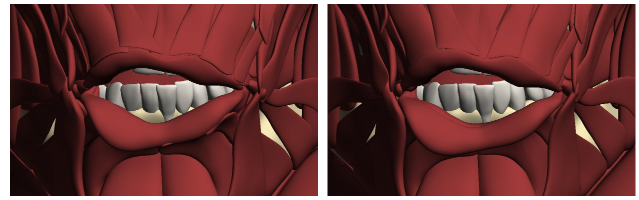

Figure 2: Left: Retargeting the creature muscle tracks using [Cong et al. 2016] results in upper and lower labial tractors deviating from their insertions along the red lip margin. Right: Adding our proposed anatomical constraints ensure the accurate insertion of these labial tractors.

the displacement of the skull attachment points and subtract this displacement from deformed vertex positions. Then, we evaluate the barycentric embeddings of the creature muscle volumes with respect to the background tetrahedralized volume to obtain the constrained creature muscle volumes. This implicitly couples overlapping muscles together because overlapping portions of muscles embedded within the same tetrahedra will move together with the same degrees of freedom on the background tetrahedralized volume thus leading to the correct anatomical behavior. See Figure 2 Right. Finally, the creature muscle tetrahedralized volumes are skinned on the creature's facial rig with the same rig parameters as the actor and used to drive a creature muscle simulation to obtain the retargeted creature facial shape. This algorithm can be repeated for each frame of an actor facial performance in order to obtain a retargeted creature facial performance.

4 RESULTS AND CONCLUSION

Figure 1 compares our approach with the prior approach of [Cong et al. 2016] and shows that our approach provides more expressiveness in the retargeted pose while cleaning up the artifacts. We have also evaluated our approach on several production shots across multiple characters and obtained improved results compared to [Cong et al. 2016]. Furthermore, many experts in this area have been impressed by the lossless nature of our retargeting algorithm. Moreover, we have demonstrated that anatomical insights can be a powerful tool for improving physically-based algorithms and we look forward to learning more about anatomy in order to further improve the fidelity our simulations.

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