Universal Capture – Image-based Facial Animation for "The Matrix Reloaded"

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Introduction

The VFX R&D stage for *The Matrix Reloaded* was kicked off in January 2000 with the challenge to create realistic human faces. We believed that traditional facial animation approaches like muscle deformers or blend shapes would simply never work, both because of the richness of facial movement and because of the human viewer's extreme sensitivity to facial nuances. Our task was further complicated as we had to recreate familiar actors such as Keanu Reeves and Lawrence Fishburne. Our team had been very successful at applying image-based techniques for photorealistic film set/location rendering, so we decided to approach the problem from the image-based side again. We wanted to produce a 3-d recording of the real actor's performance and be able to play it back from different angles and under different lighting conditions. Just as we can extract geometry, texture, or light from images, we are now able to extract movement. Universal Capture combines two powerful computer vision techniques: optical flow and photogrammetry.

HiDef Capture Setup

We used a carefully placed array of five synchronized cameras that captured the actor's performance in ambient lighting. For the best image quality we deployed a sophisticated arrangement of Sony/Panavision HDW-F900 cameras and computer workstations that captured the images in uncompressed digital format straight to hard disks at data rates close to 1G/sec.

Optical Flow + Photogrammetry

We use optical flow to track each pixel's motion over time in each camera view. The result of this process is then combined with a cyberscan model of a neutral expression of the actor and with photogrammetric reconstruction of the camera positions. The algorithm works by projecting a vertex of the model into each of the cameras and then tracking the motion of that vertex in 2-d using the optical flow where at each frame the 3-d position is estimated using triangulation. The result is an accurate reconstruction of the path of each vertex though 3-d space over time.

Keyshaping, Adapt, Removing Global Motion

Optical flow errors can accumulate over time, causing an undesirable drift in the 3-d reconstruction. To minimize the drift we make use of reverse optical flow. On this production the problem was eliminated by introducing a manual keyshaping step: when the flow error becomes unacceptably large the geometry is manually corrected and the correction is then algorithmically propagated to previous frames.

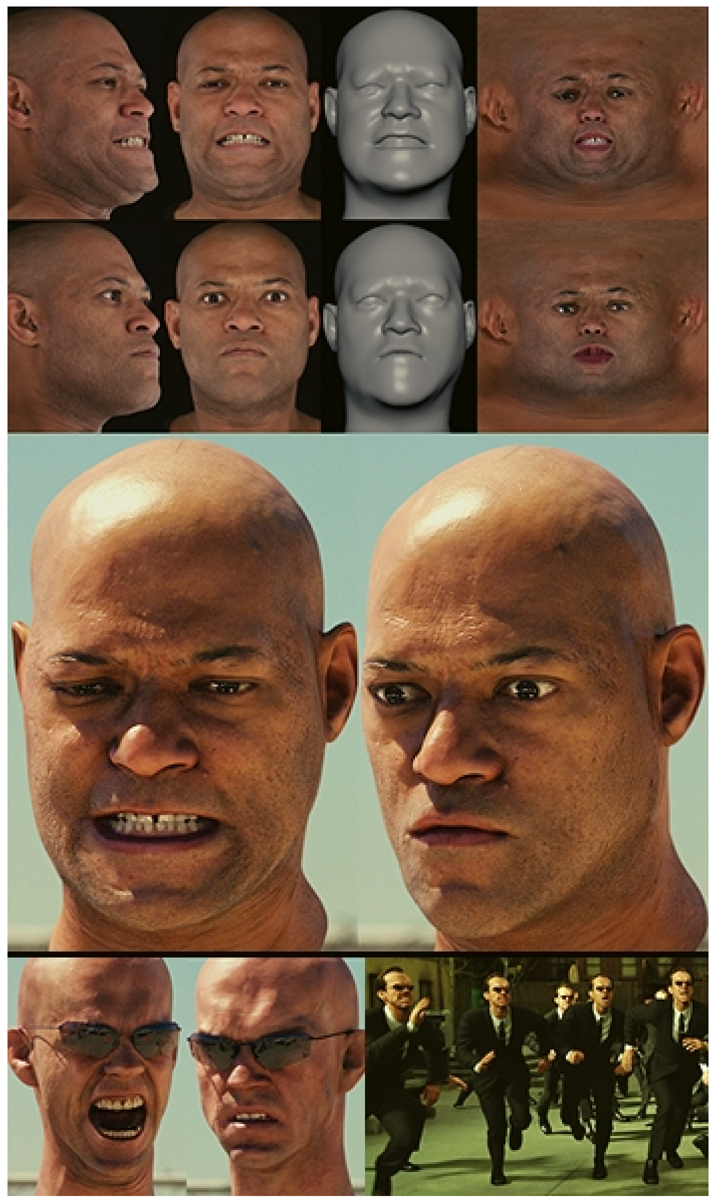
The reconstructed motion contains the global "rigid" head movement. In order to attach facial performances to CG bodies or blend between different performances this movement must be removed. We estimate the rigid transformation using a least squares fit of a neutral face and then subtract this motion to obtain the non-rigid deformation.

Texture Map Extraction

No believable facial rendering can be done without varying the face texture over time. The fact that we did not use any markers on the face to assist feature tracking gave us the important advantage that we could combine the images from the multiple camera views over time to produce animated seamless UV color maps capturing important textural variation across the face, such as the forming of fine wrinkles or changes in color due to strain, in high-res detail on each side of the face.

Rendering

Although the extracted facial animation had most of the motion nuances it lacked the small-scale surface detail like pores and wrinkles. We obtained that by using a highly detailed 100-micron scan of the actor's face. The detail is then extracted in a bump (displacement) map. Dynamic wrinkles were identified by image processing on the texture maps; these are then isolated and layered over the static bump map. We then combine these with image-based skin BRDF estimation, subsurface scattering approximation, and real-world lighting reconstruction for the highly photorealistic human face renderings below.



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