Spring 2018

CSCI 621: **Digital Geometry Processing**

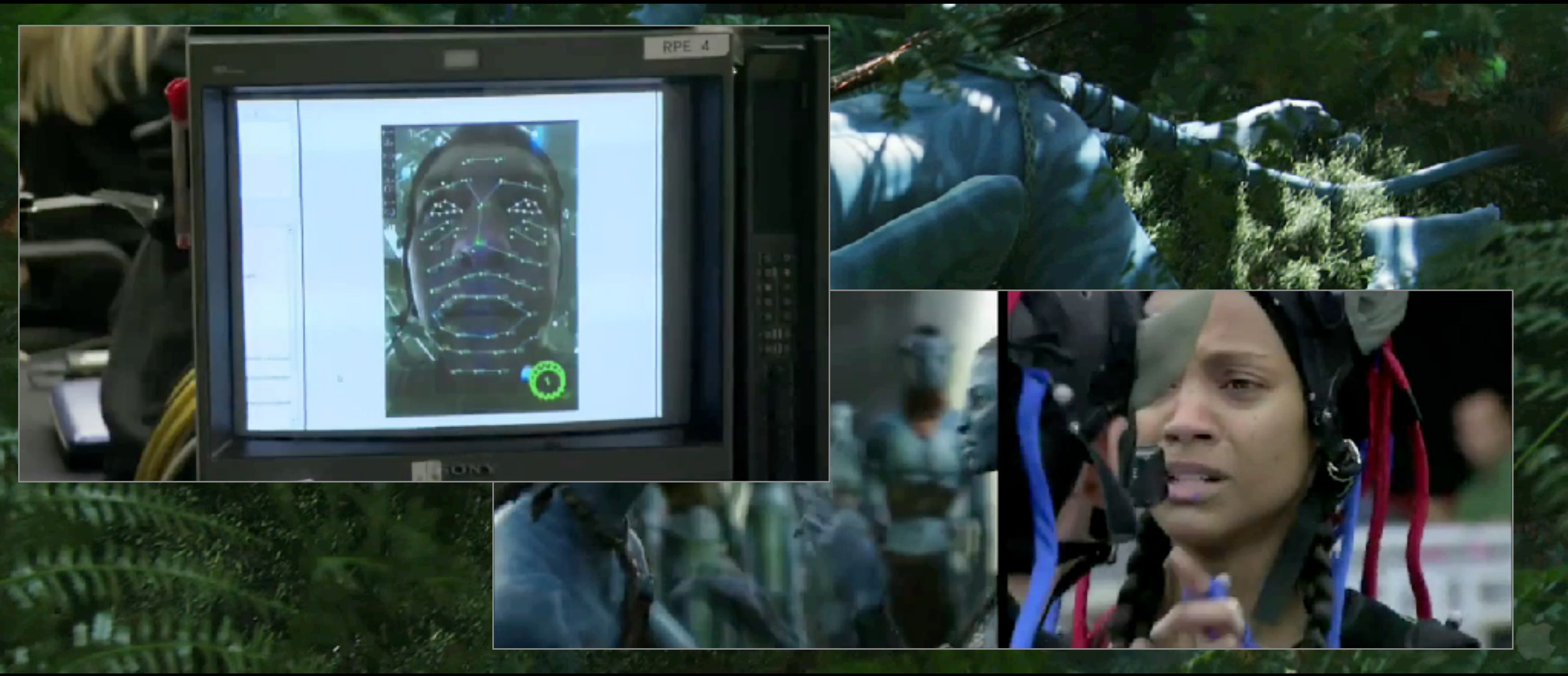
15 **Facial Performance Capture**

Hao Li

http://cs621.hao-li.com

Performance to Facial Animation

Motion Capture



Motion Capture

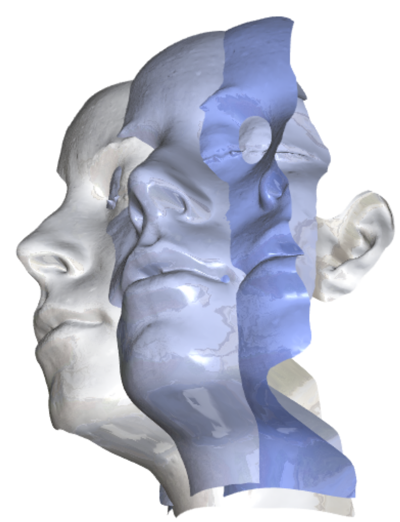
Facial Animation in Films


Weta Digital

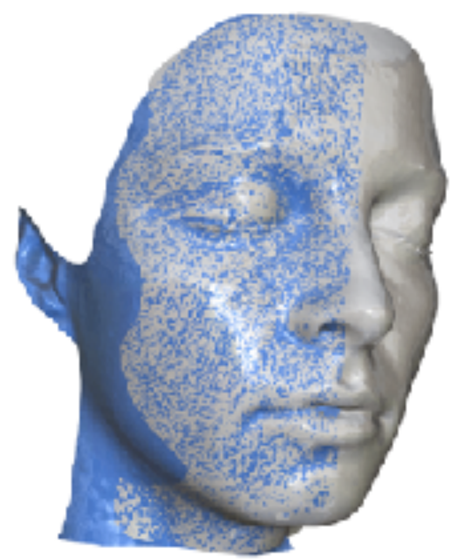
Facial Modeling and Scanning

Facial Modeling and Scanning

acquisition



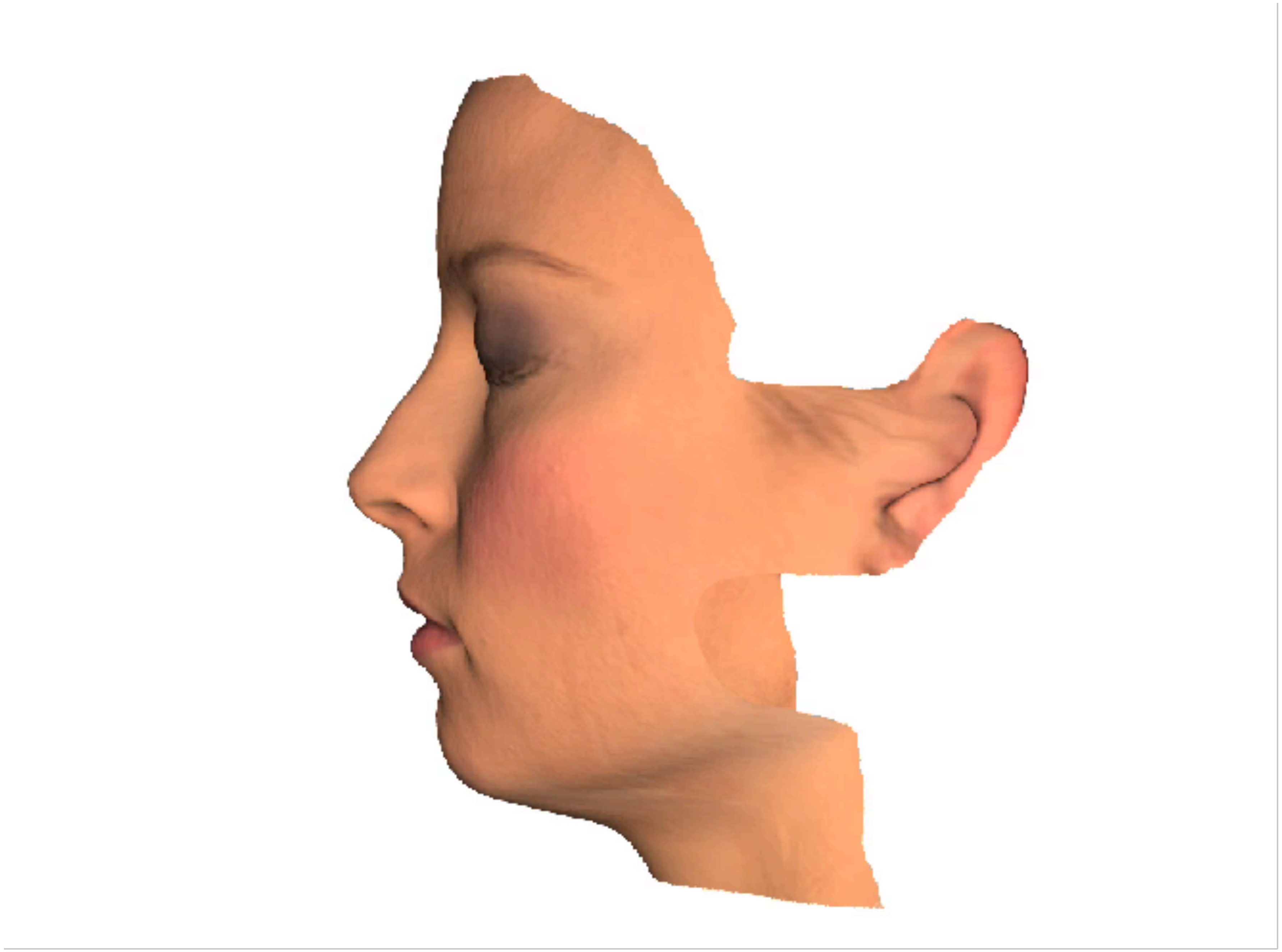
initial alignment



registration

merging

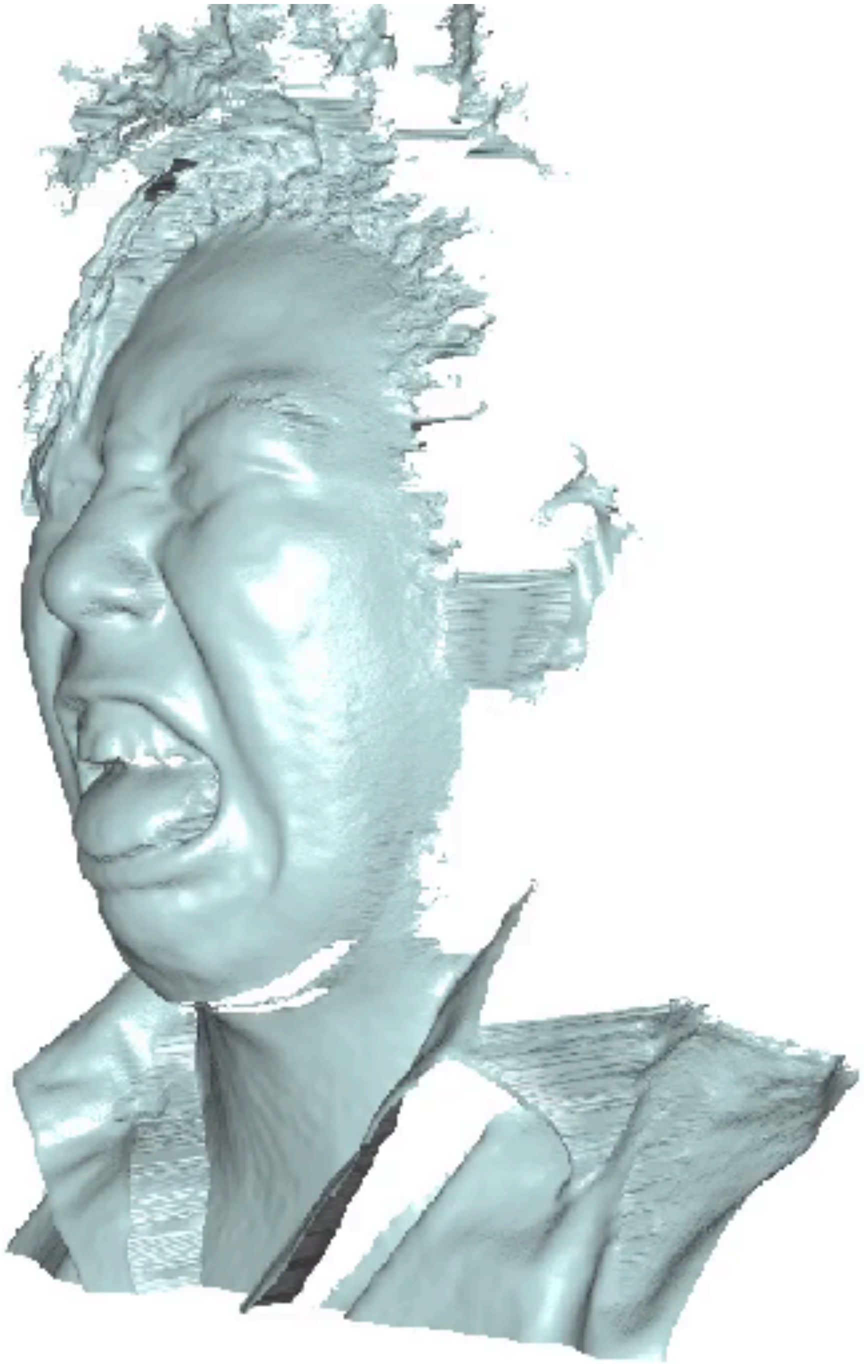
Facial Modeling and Scanning



High-End 3D Scanning

Low-Cost Passive Scanning (AGI Soft)

stereo pair

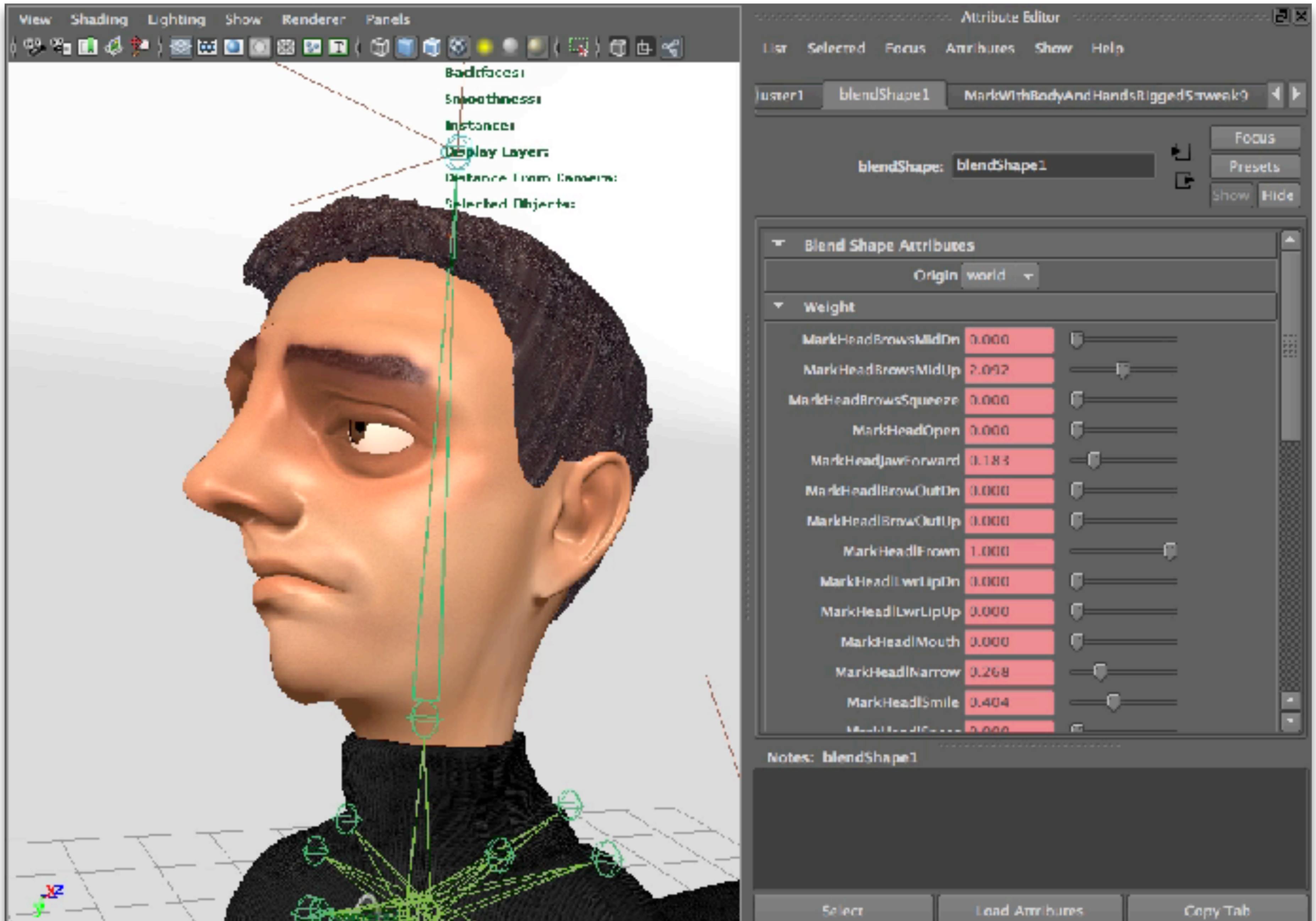


3D scan

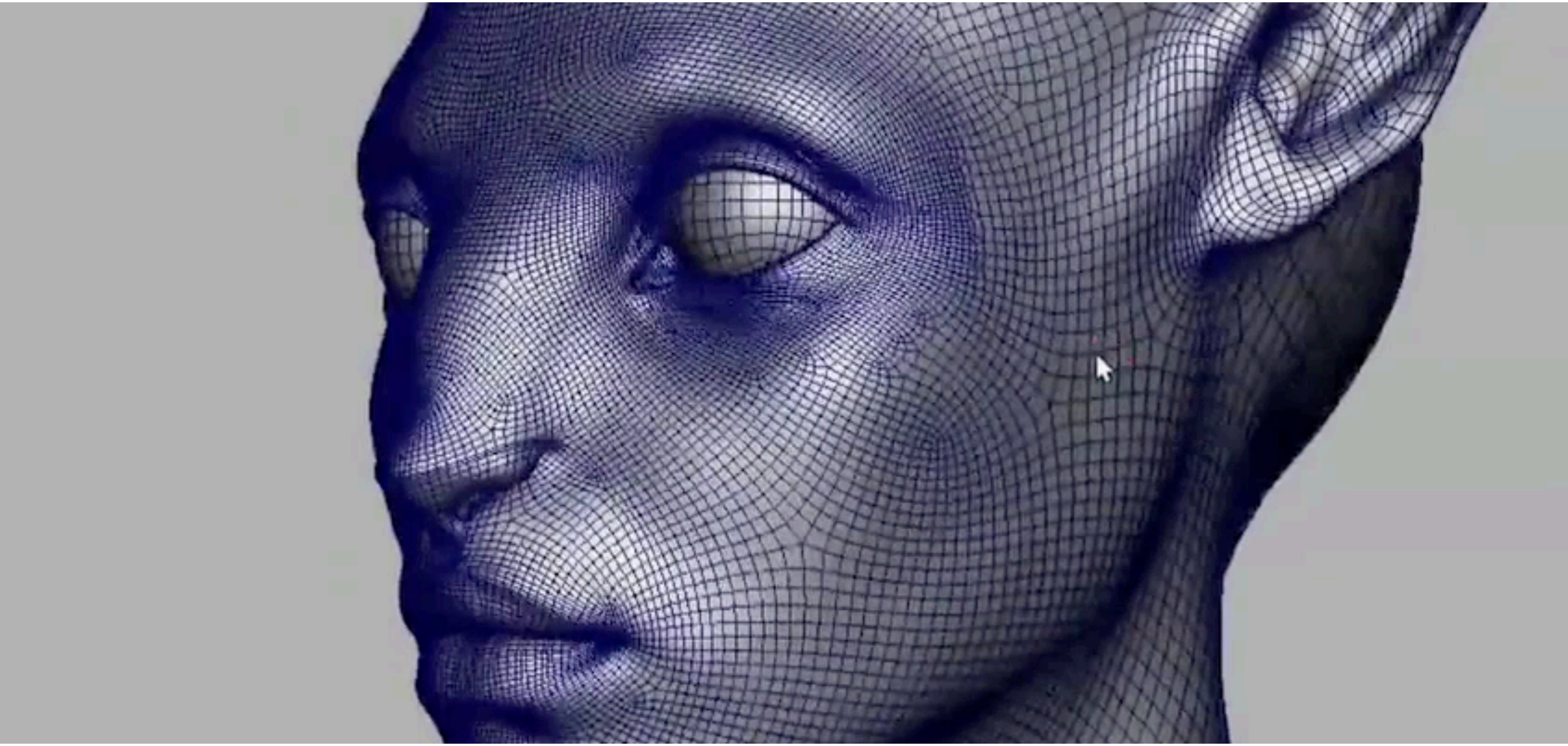
Low-Cost Active Scanning

Microsoft Kinect & Kinect Fusion

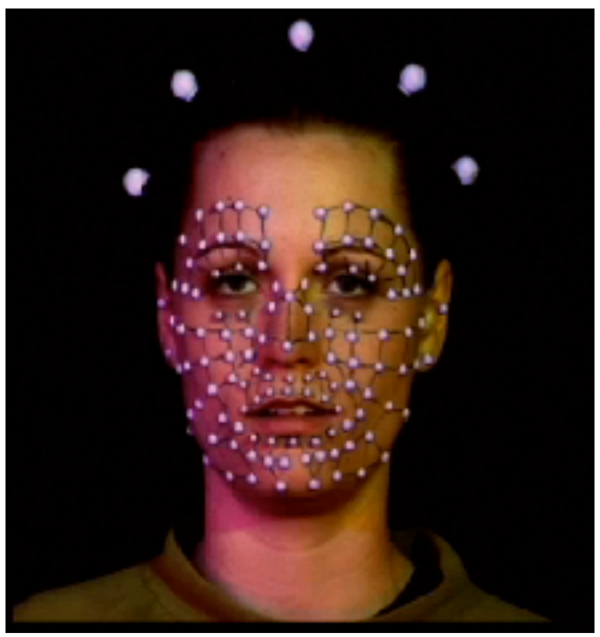
Rigging & Animation



Blendshapes & Correctives for Realism



Motion Capture Technologies



Sparse Markers

Dense Markers

MOVA

Markerless

Image Metrics

Using Markers

input performance

input video
with markers

tracking

retargeting

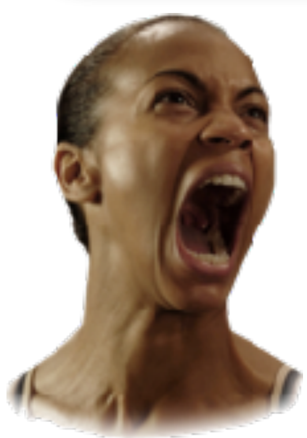
Using Dense Markers

Vision-Based Tracking **& Texturing**

LA Noire

Typical **Animation Workflow in Industry**

3D Scanning → Modeling + Fitting → Light-weight Rigging → Motion Capture → Cleanup & Key-Framing



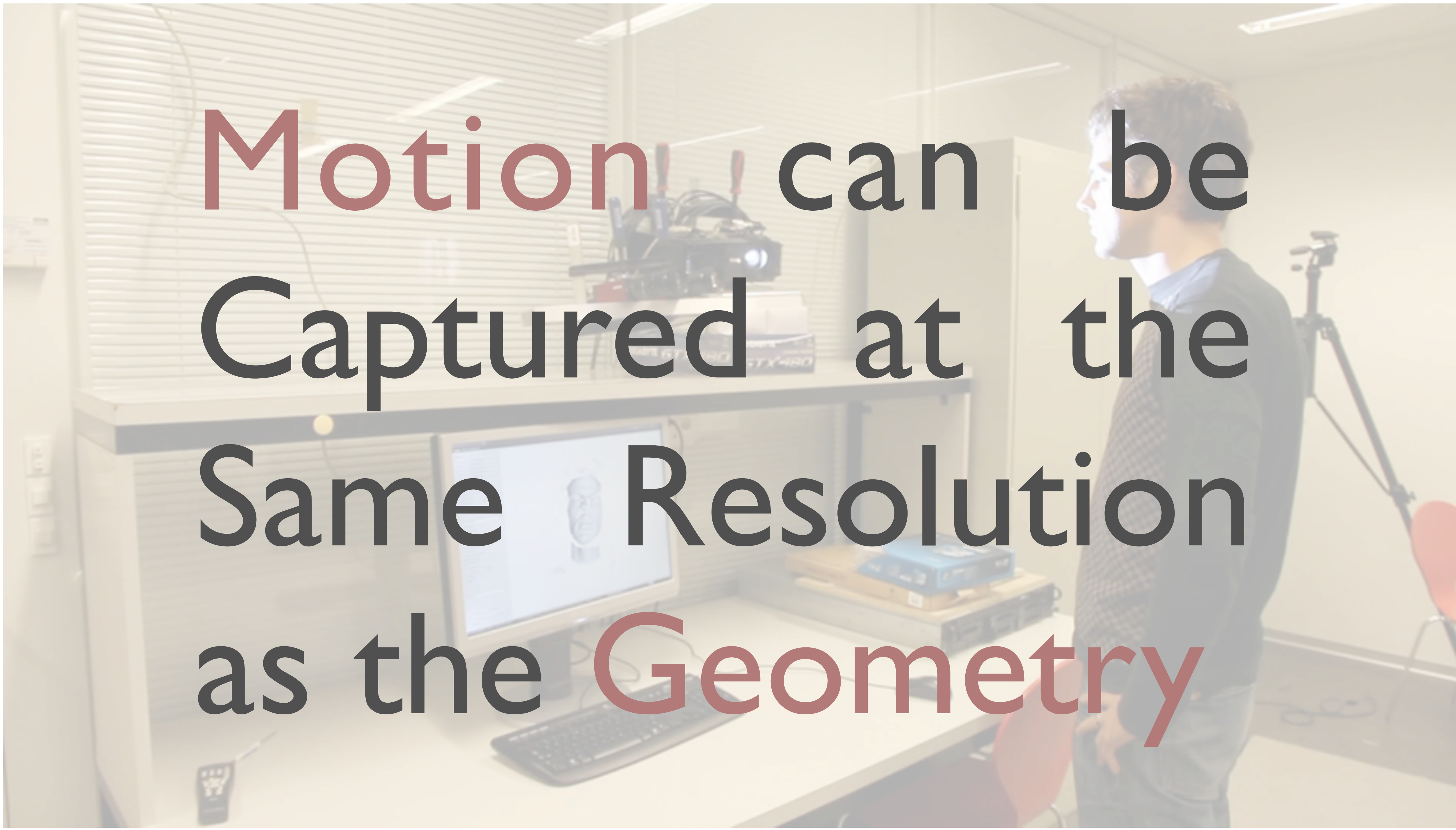
Source Character

Modeling → Complex Rigging → Retargeting → Key-Framing + Proc.+Sim.

Target Character

Markerless Facial Capture

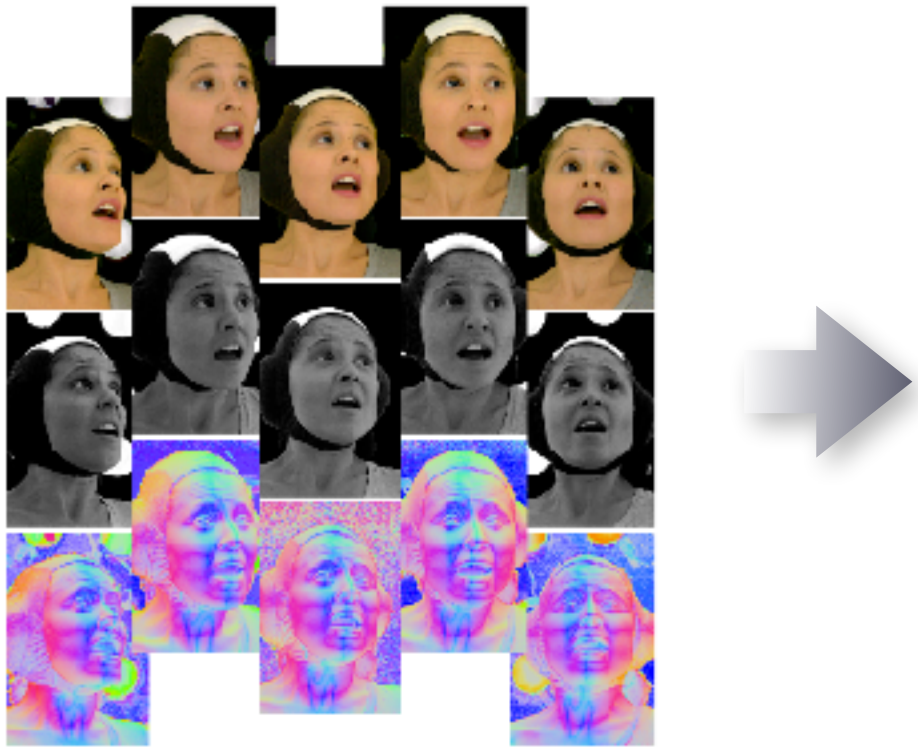
3D Range Sensor



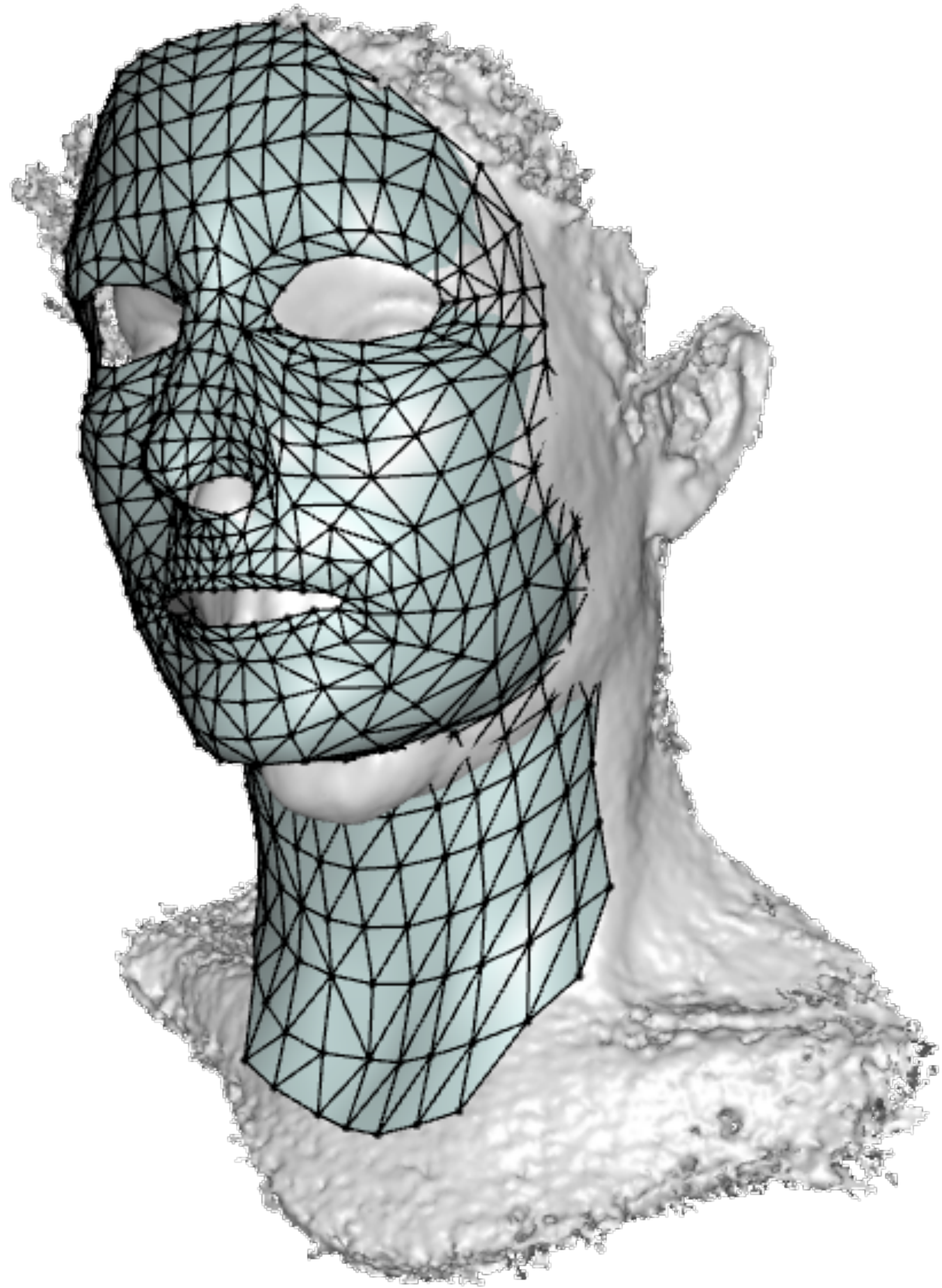
Motion can be Captured at the Same Resolution as the Geometry

Vapor Ware? (Spatial Phase Imaging)

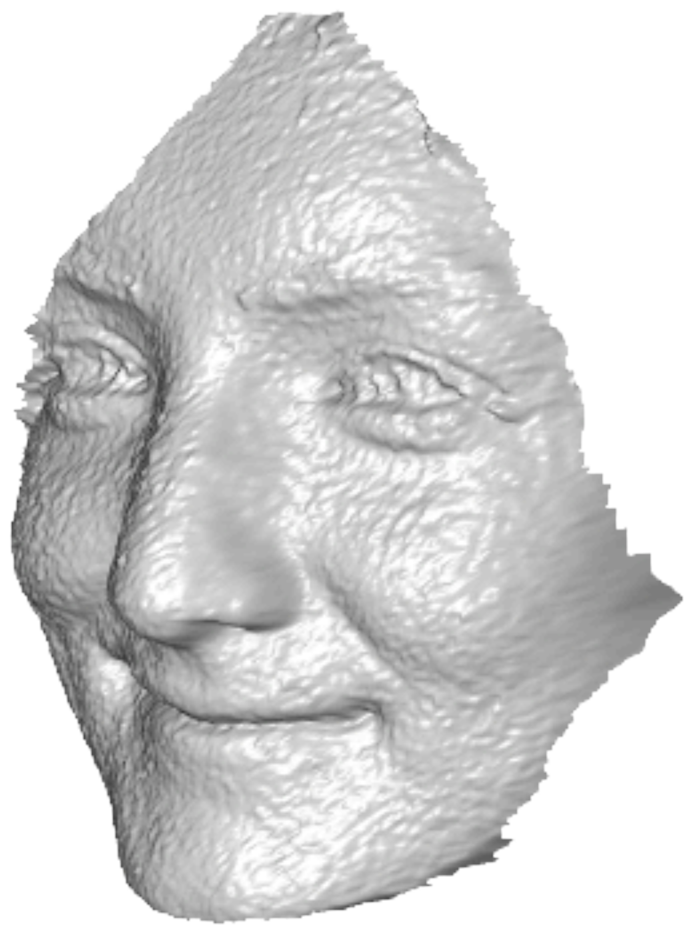
USC ICT Light Stage 5



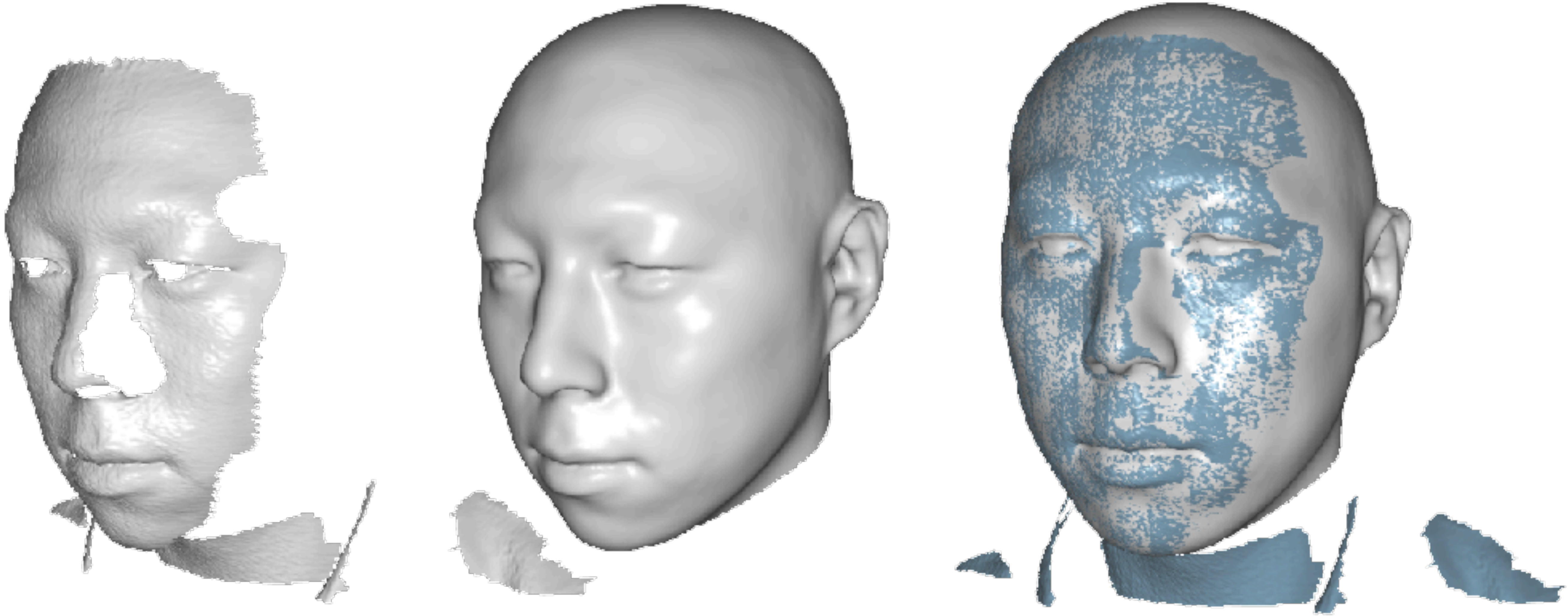
Template Fitting



Template Fitting with PCA



Template Based Tracking



Overview

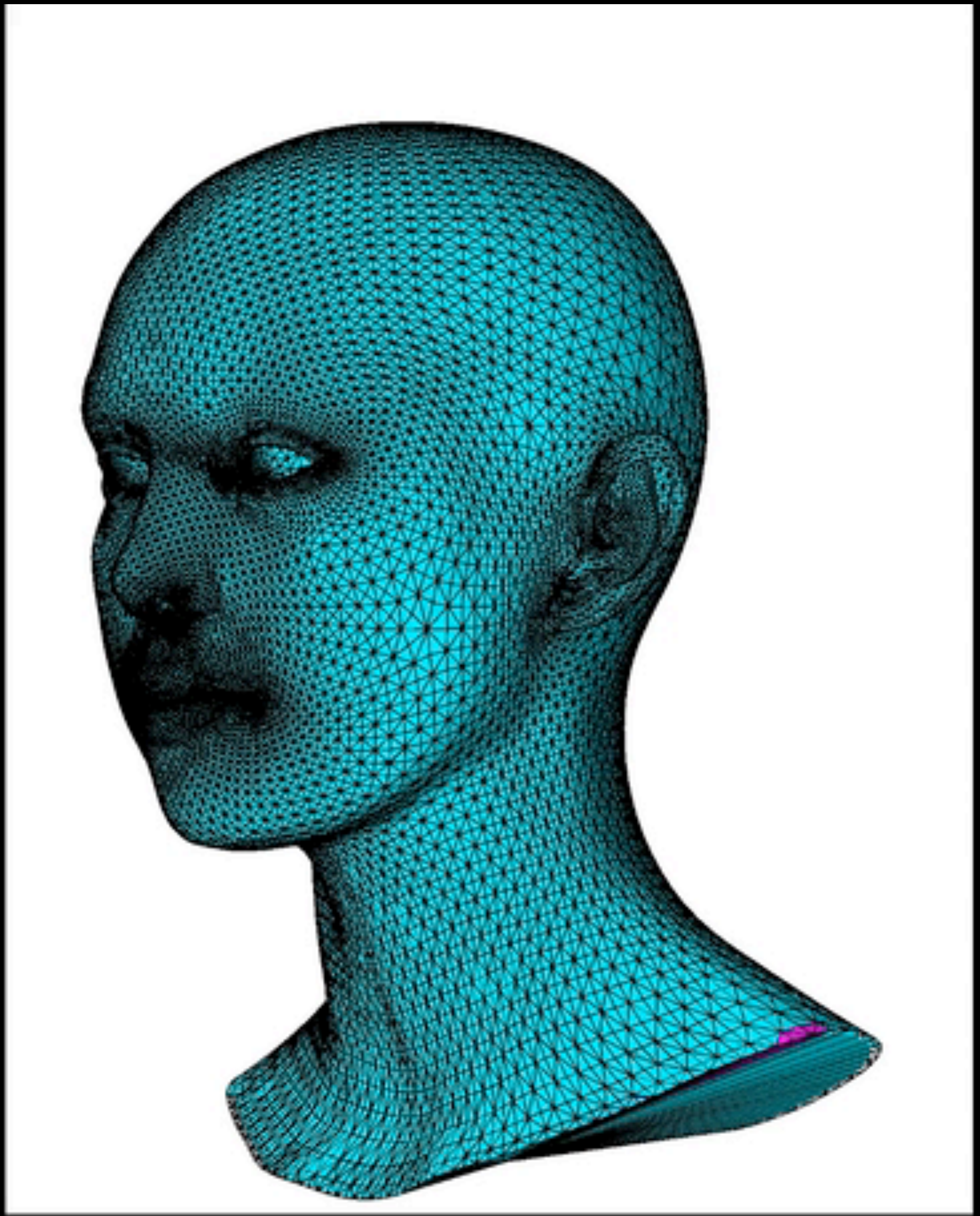
Using Light Stage X

Using Light Stage X

Facial Performance Captured under static Fullon BLUE LEDs

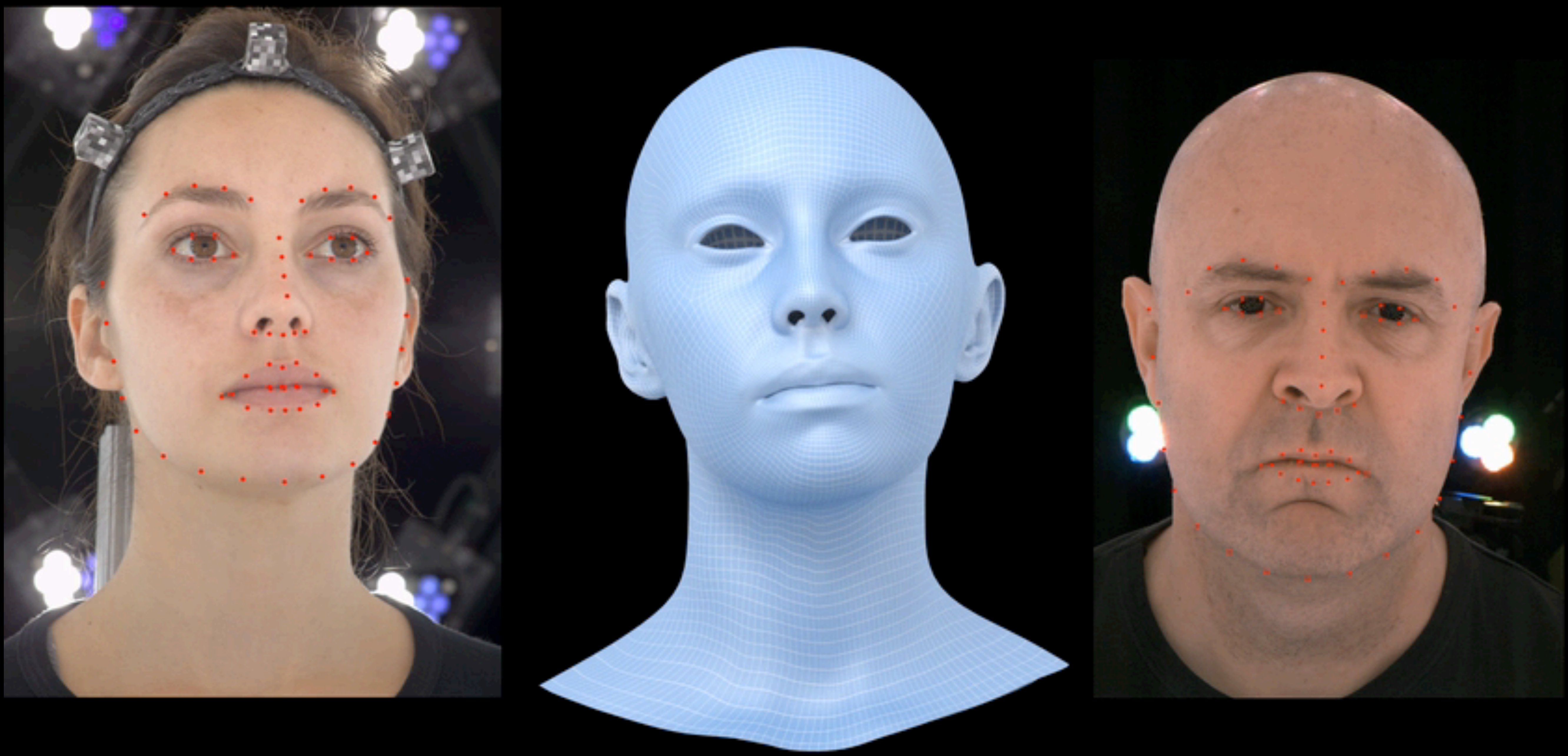
Using Light Stage X

Artist Quality Template



Tetrahedral Mesh Constructed From the Surface

Using Light Stage X

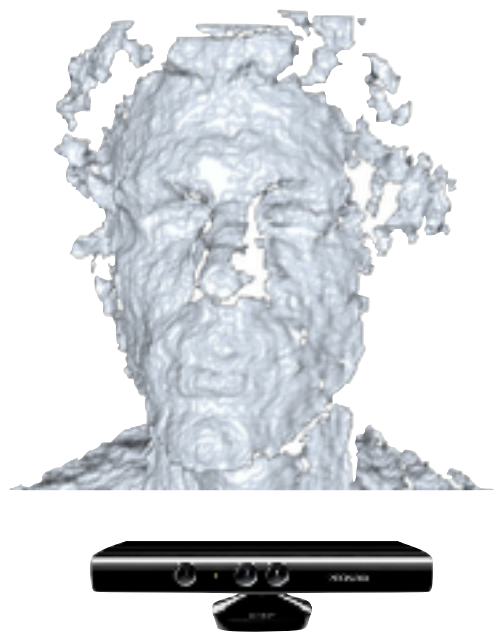


Initial Deformation Based on Facial andmarks

Using Light Stage X

Performance Tracking of Multiple Subject using a Shared Template

Requirements for a Practical System



1. Real-time performance

2. Robustness to noise

3. High-level semantics

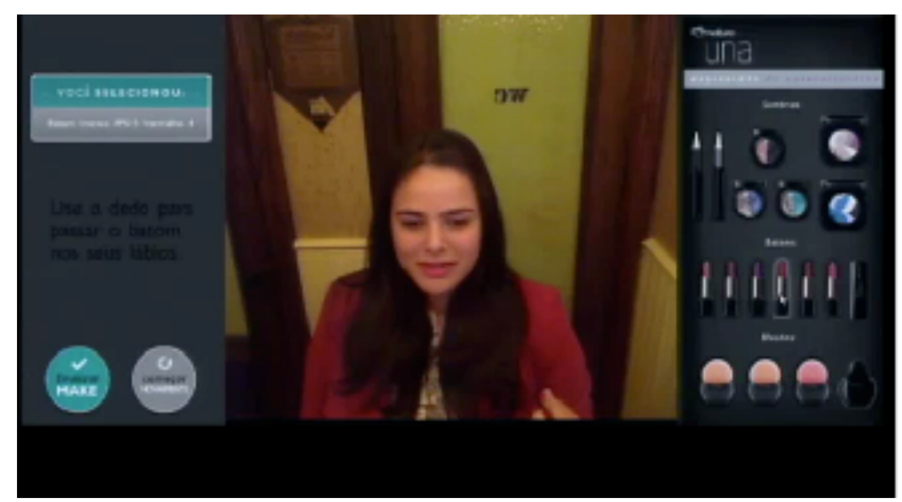
Realtime Facial Capture

Why Realtime?

VFX/Game Production

Virtual Avatars

Robotics



AR/Virtual Mirror

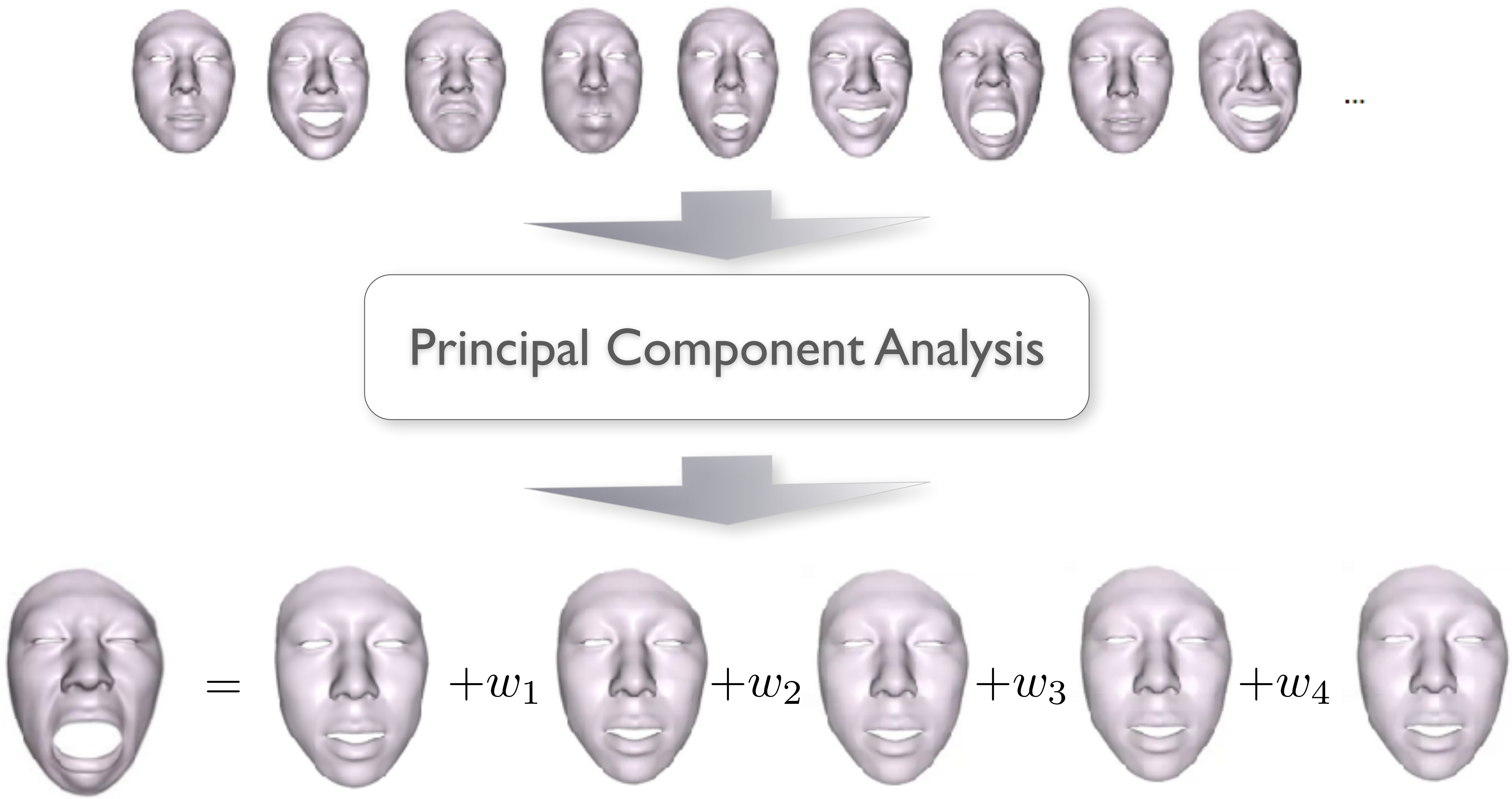
Objective

Building Expression Space

tracked template

input scan

Expression PCA for Reduced Dimension



Realtime Systems

depth sensor as input

with training
Weise et al. SCA 09

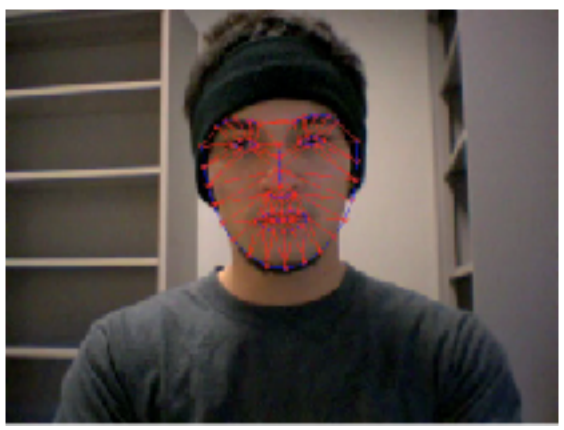
with little training
Li et al. Siggraph 2010

little to no training
Weise et al. Siggraph 2011 &
Bouaziz et al. Siggraph 2013

reduced calibration and more accessible

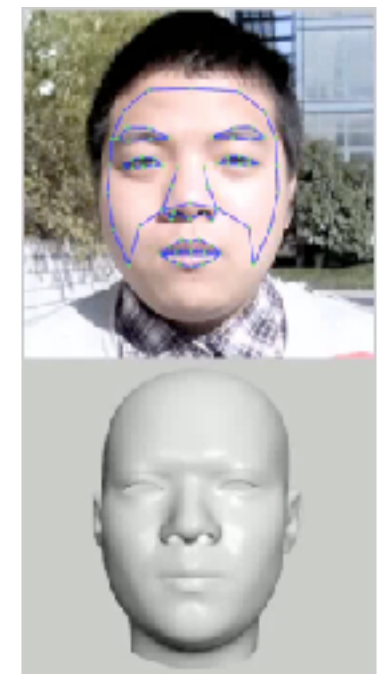
Realtime Systems

video as input



without training
Saragih et al. IJCV 2011

without training
Image Metrics 2011



with training
Cao et al. Siggraph 2013

increased accuracy and expressiveness

Automatic Facial Rigging

Blendshape Animation

Blendshape Animation

blending weights

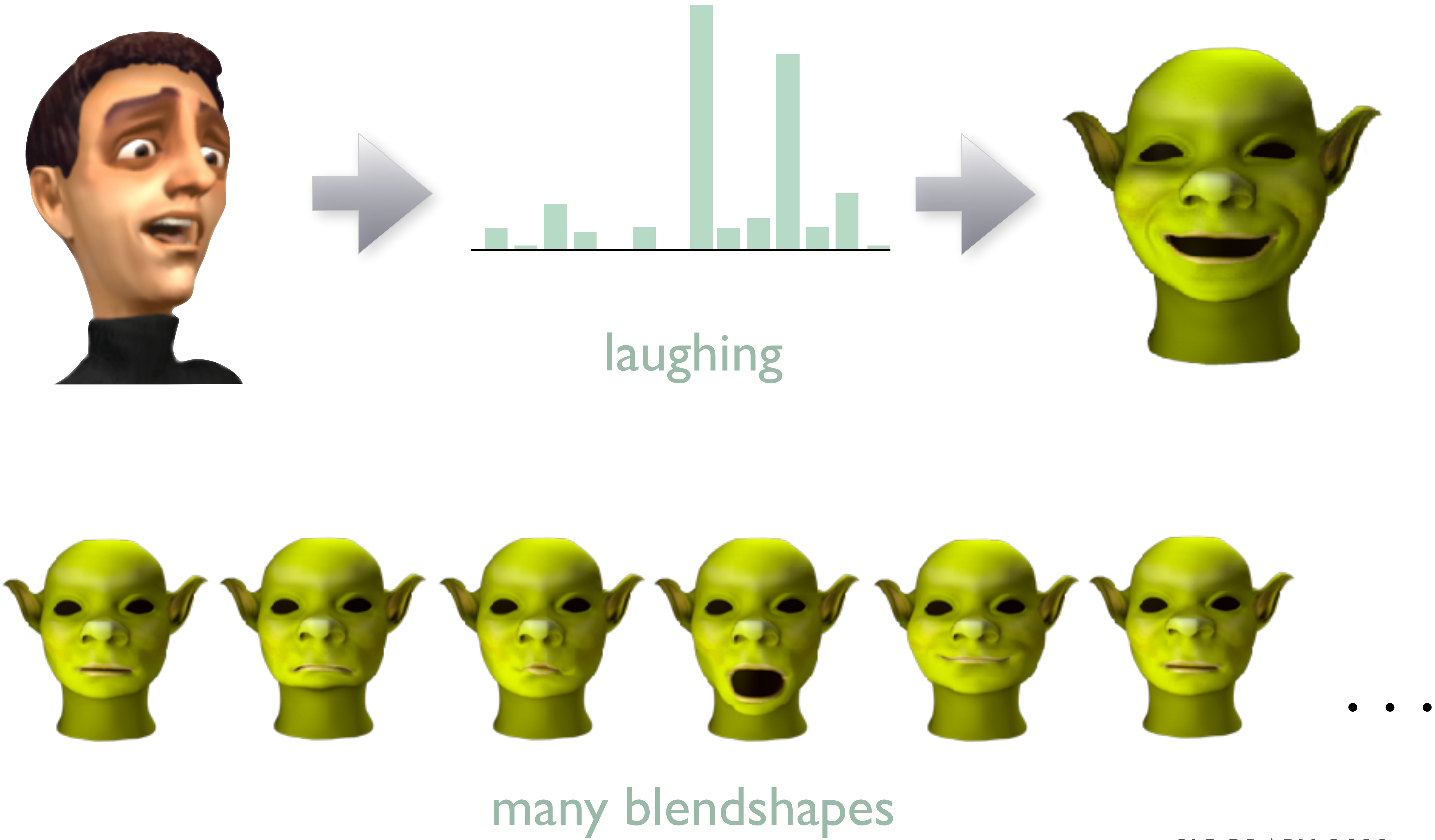
laughing

$$= B_0 + \alpha_1 B_1 + \alpha_2 B_2 + \alpha_3 B_3 + \ldots$$

neutral face

blendshapes

Blendshape Retargeting



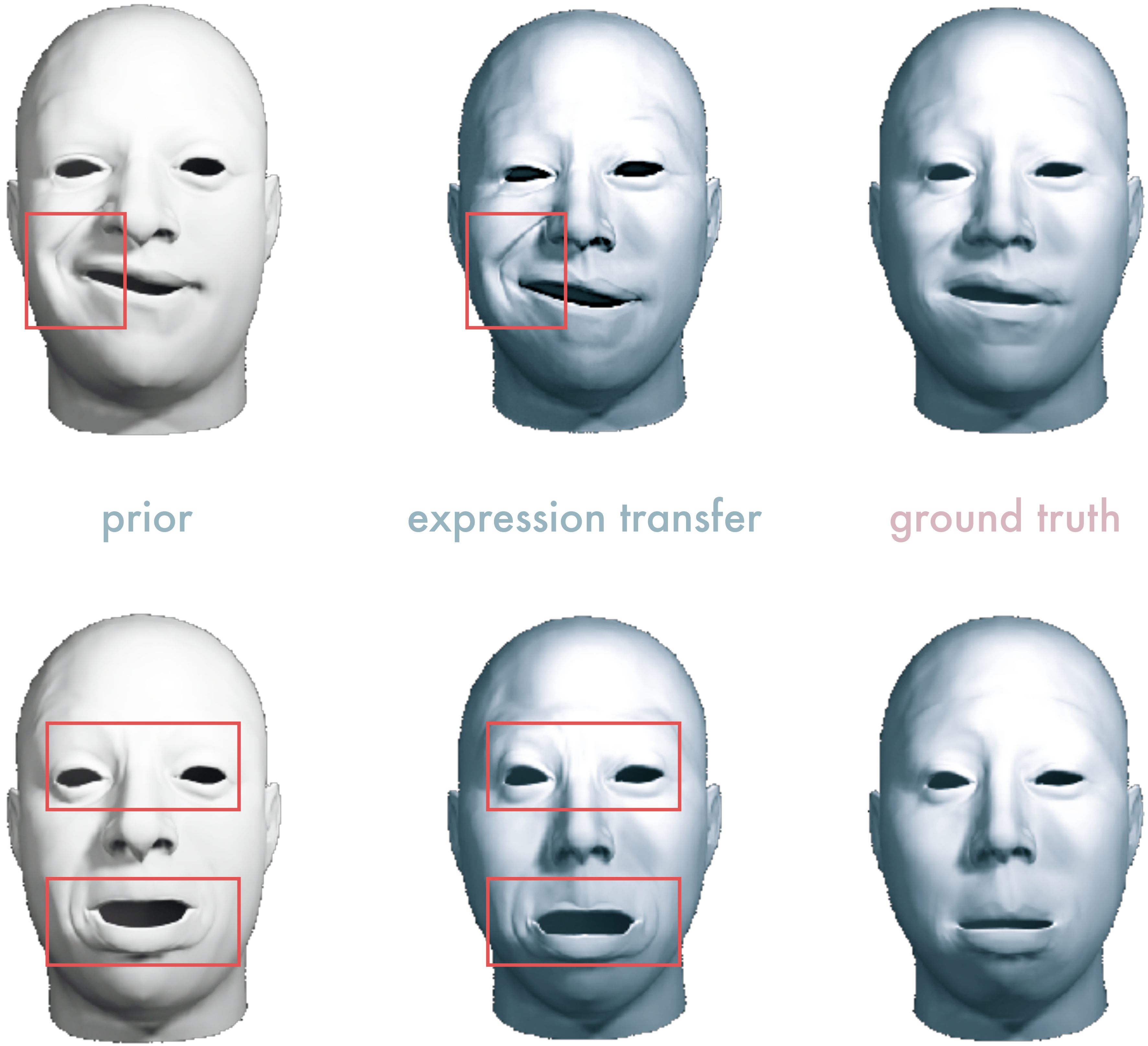
Expression Transfer

prior
blendshapes

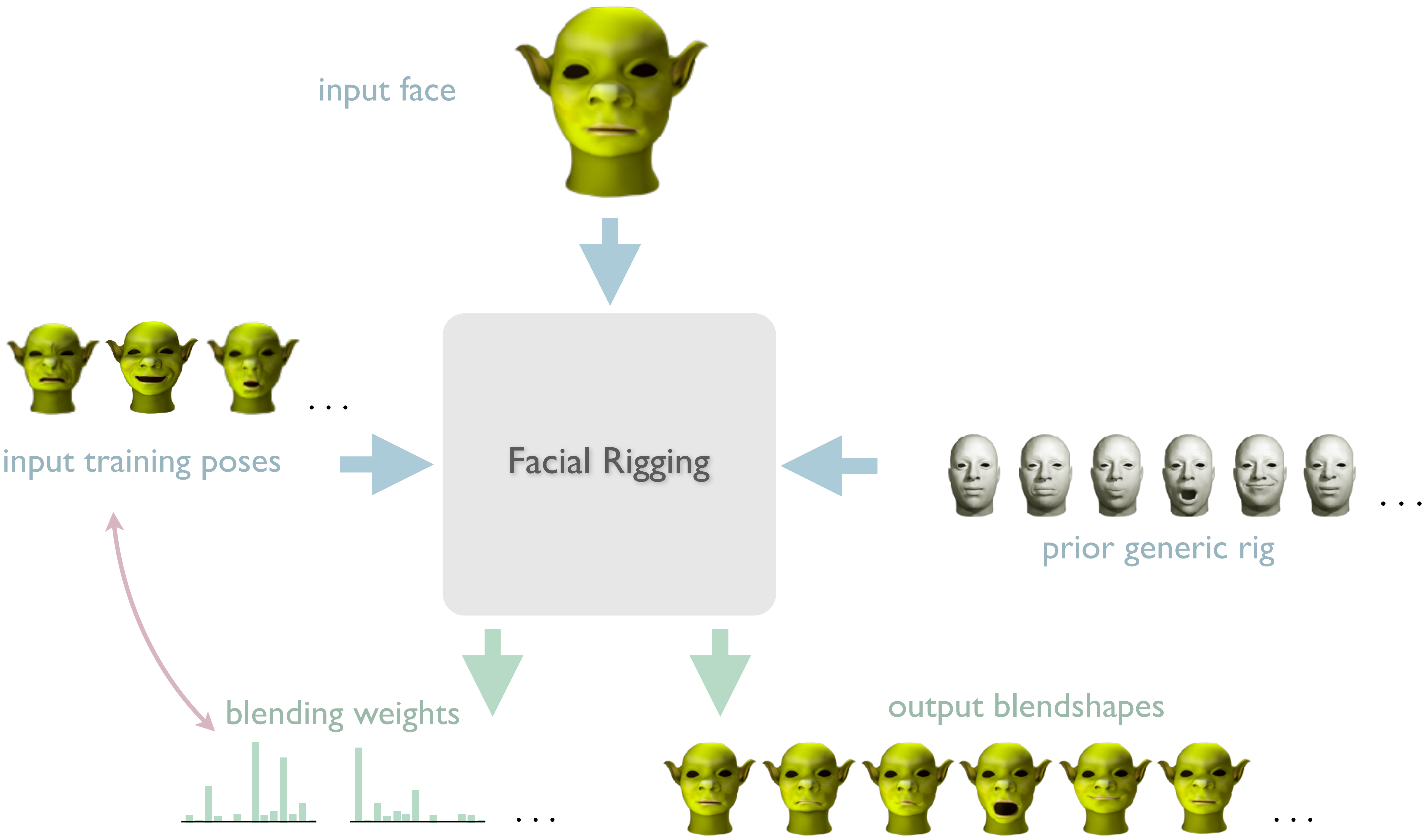
[Noh & Neumann '01]
[Sumner & Popovic '04]

reconstructed
blendshapes

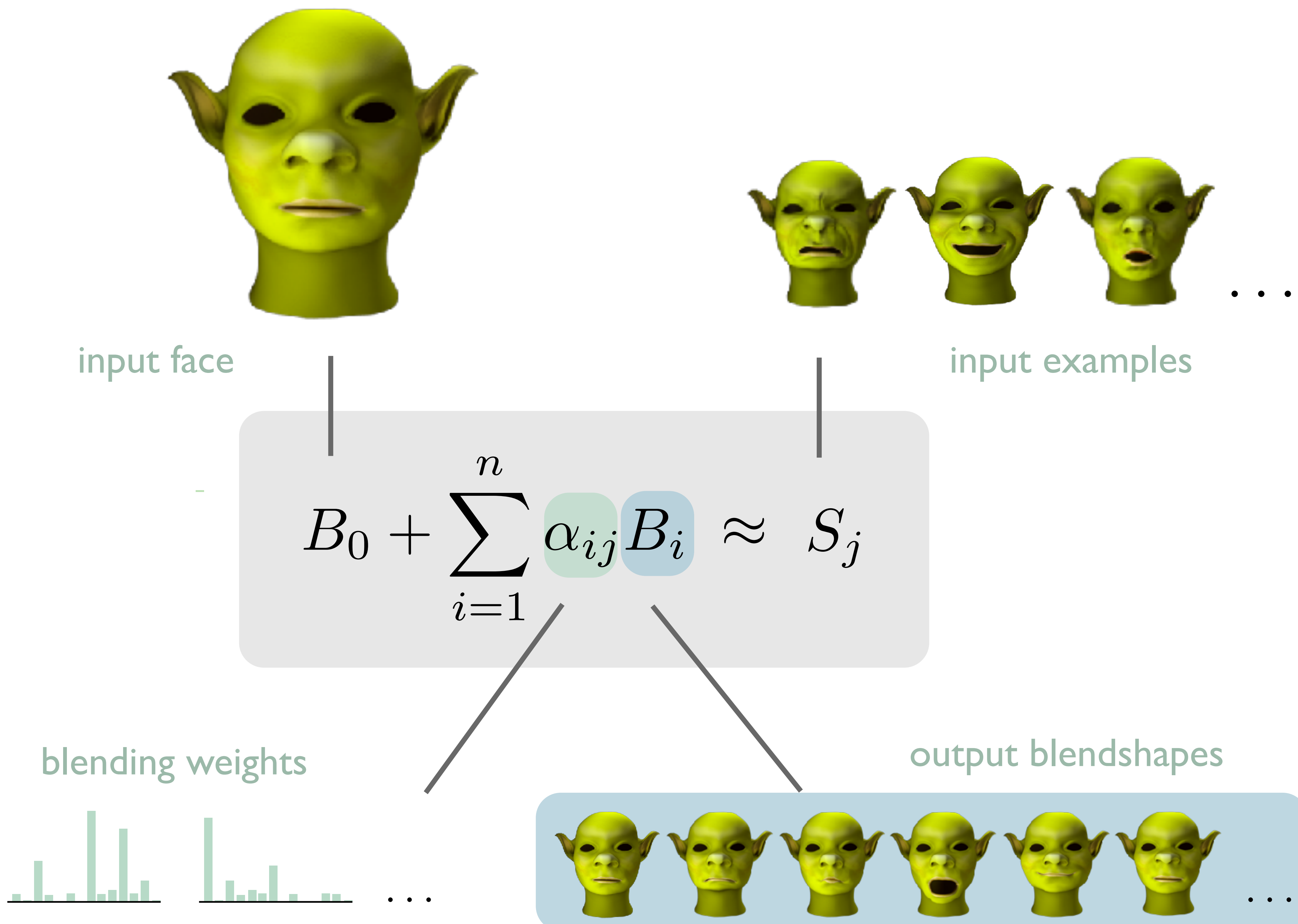
Problems



Example Based-Facial Rigging



Bilinear Problem



$$B_0 + \sum_{i=1}^{n} \alpha_{ij} B_i \approx S_j$$

Decoupled Optimization

$$B_0 + \sum_{i=1}^{n} \alpha_{ij} B_i \;\approx\; S_j$$

Decoupled Optimization

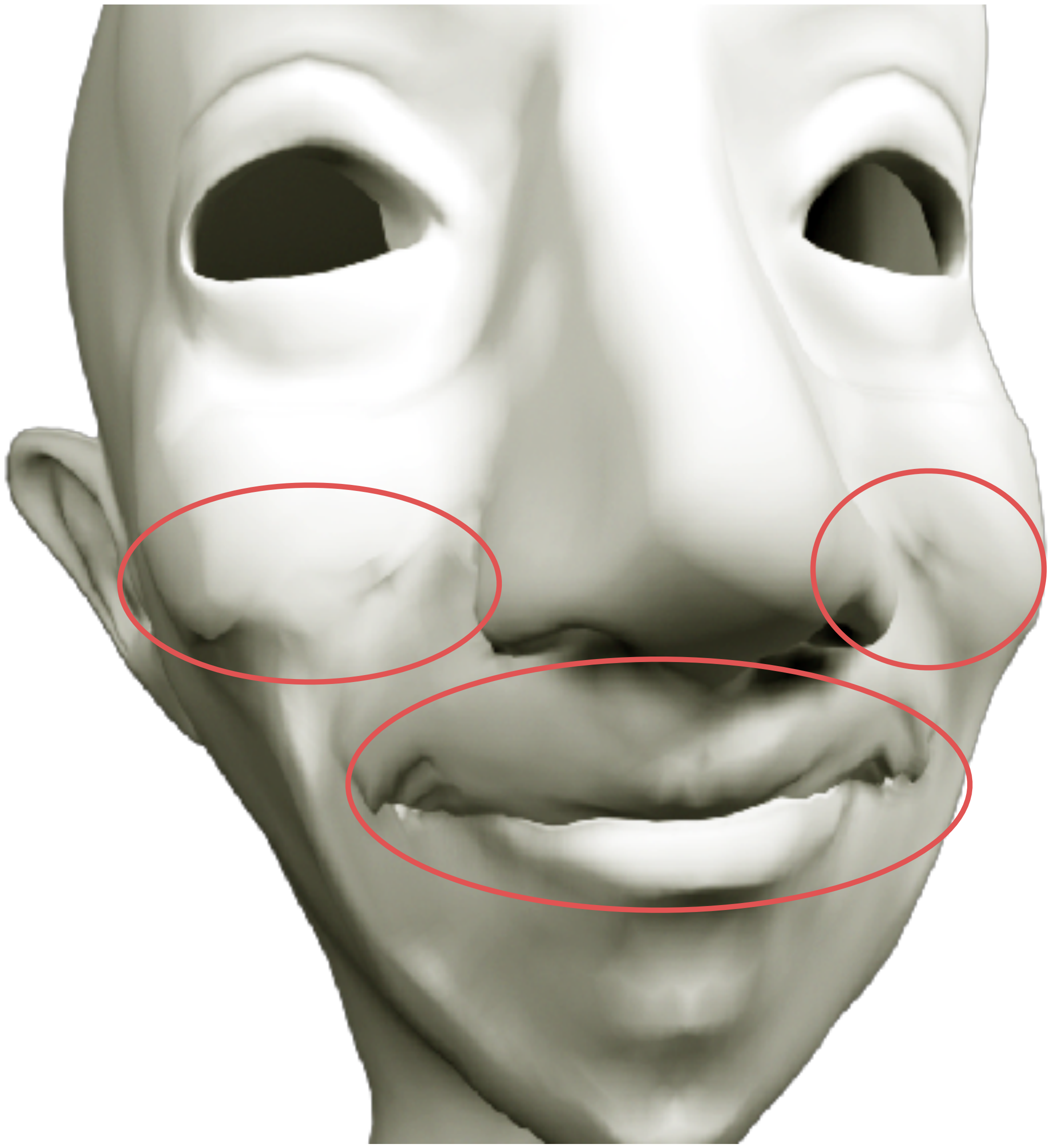
Step A

$$B_0 + \sum_{i=1}^{n} \alpha_{ij} B_i \approx S_j$$

Step B

$$B_0 + \sum_{i=1}^{n} \alpha_{ij} B_i \approx S_j$$

Gradient Domain Optimization



$$\underset{B_i}{\operatorname{argmin}} \|B_0 + \sum_{i=1}^{n} \alpha_{ij} B_i - S_j\|^2 + \beta \|B_i - \tilde{B}_i\|^2$$

$$\underset{M_i}{\operatorname{argmin}} \|M_0 + \sum_{i=1}^{n} \alpha_{ij} M_i - M_j^S\|^2 + \beta \|M_i + M_0 - G_i \cdot M_0\|^2$$

Comparison

prior | without examples | with 6 examples | input example

whistle | surprise

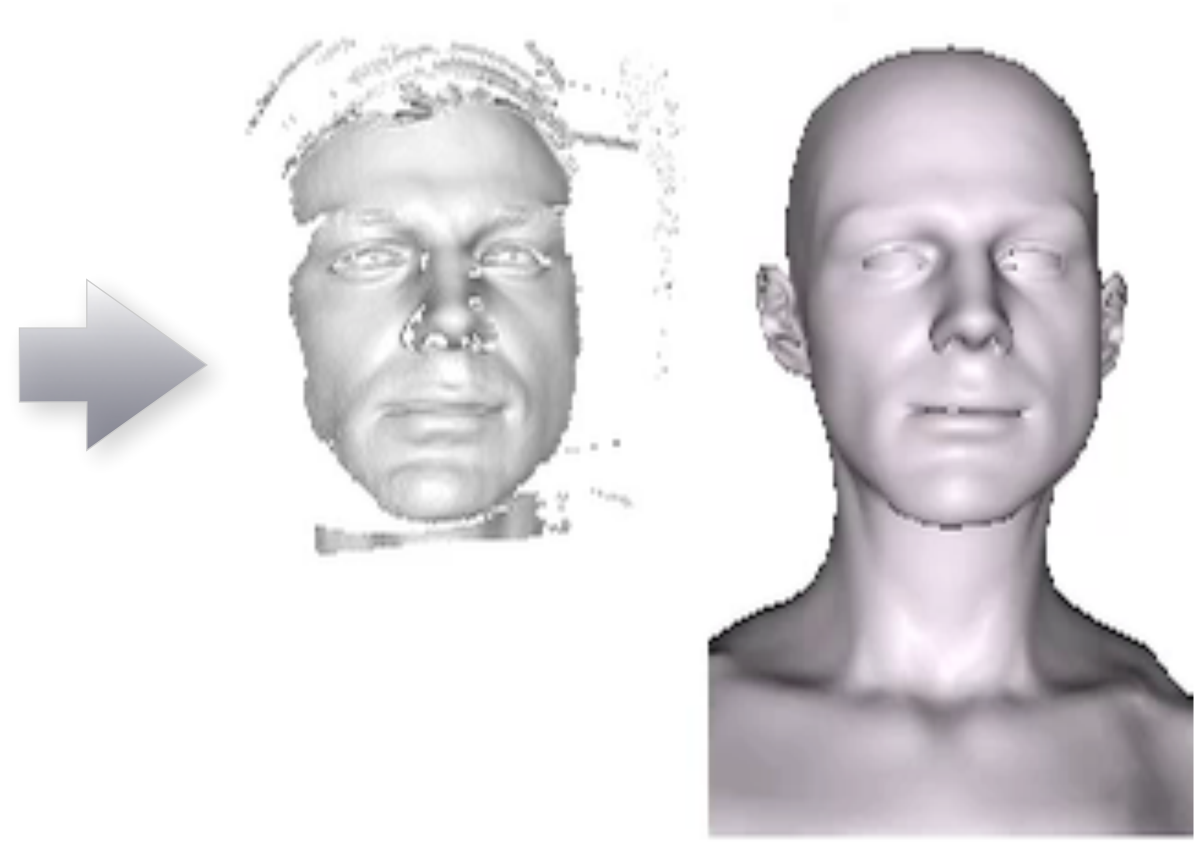
Directable Facial Animation

3D scans

facial tracking

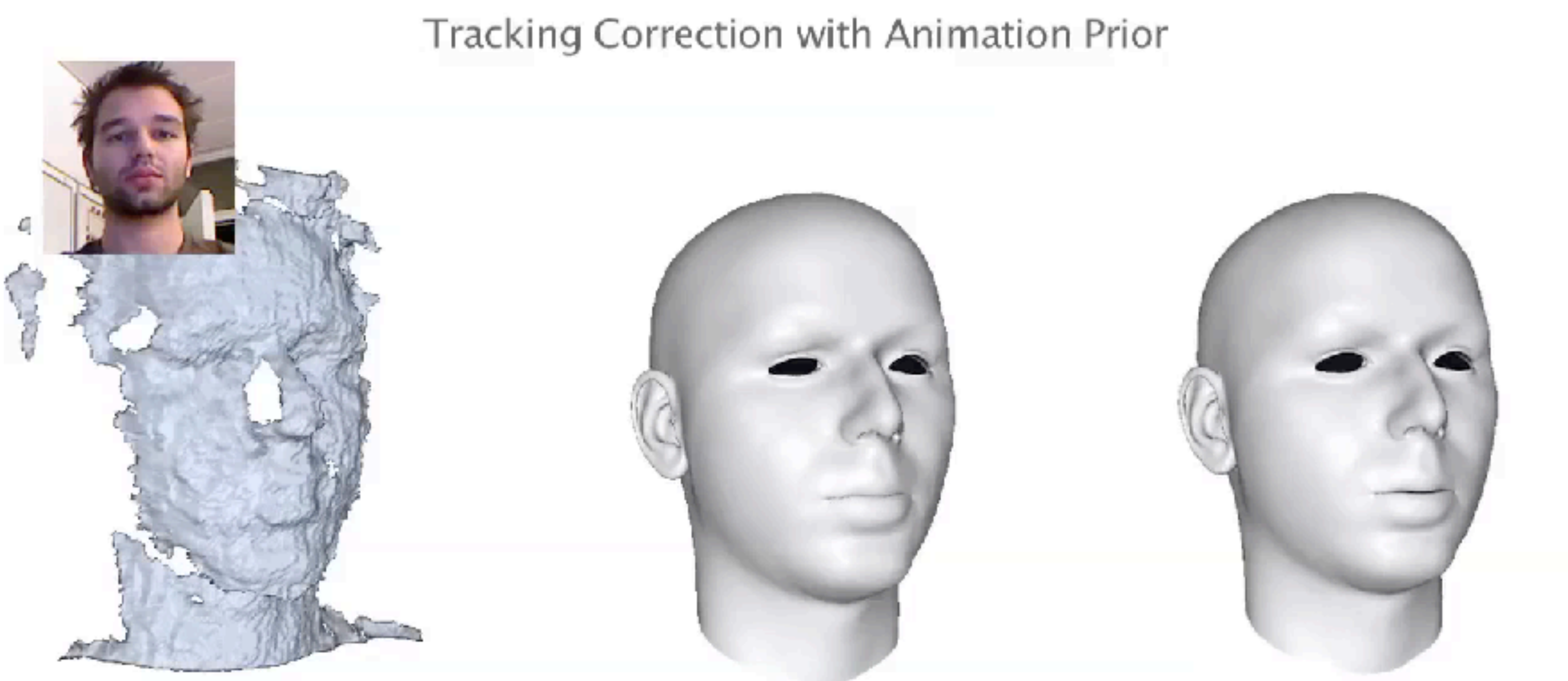
Blendshapes for Tracking

ICP with Blendshapes



Animation Prior

Problem: **Noisy Input**

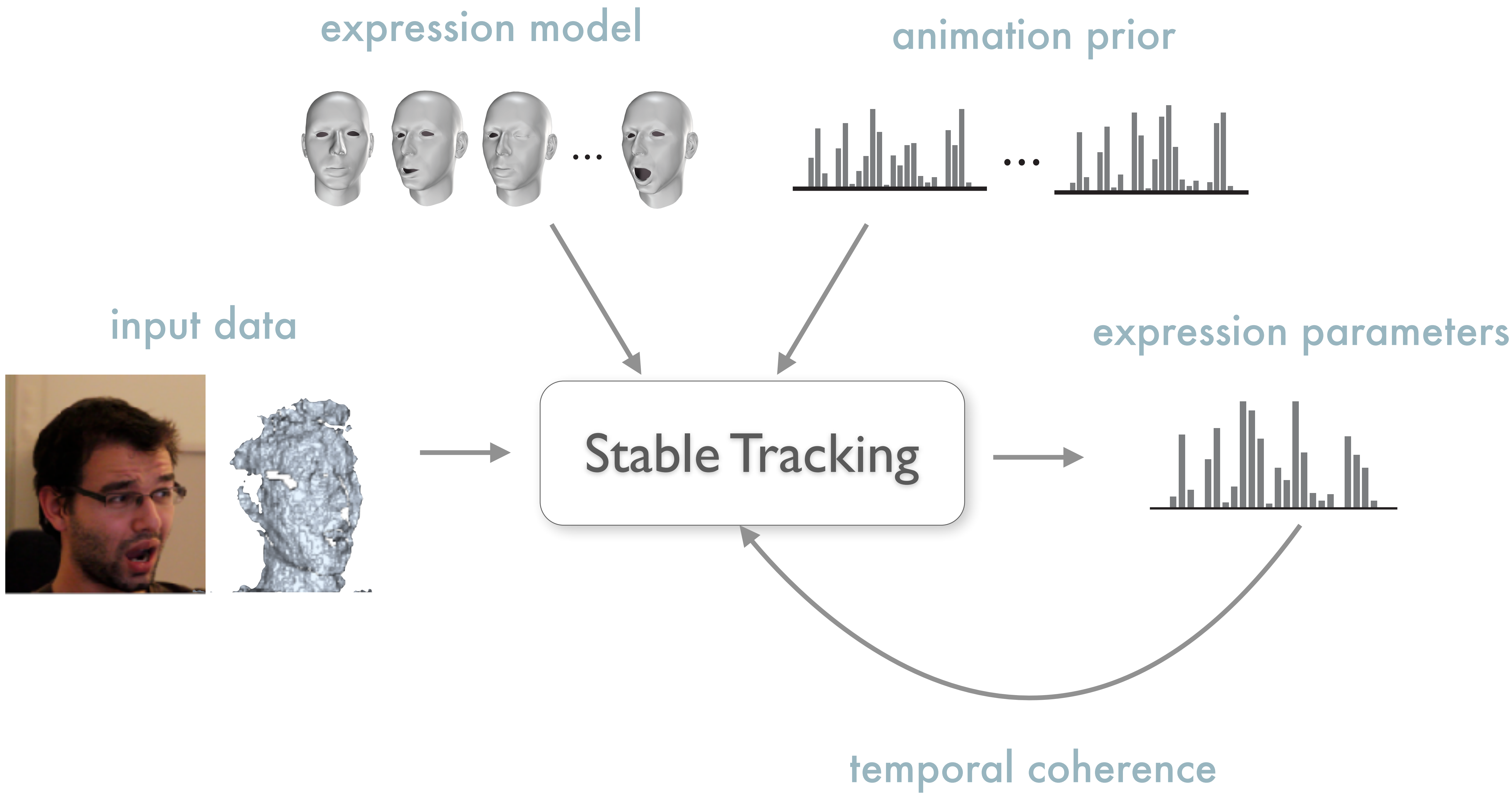


input scans

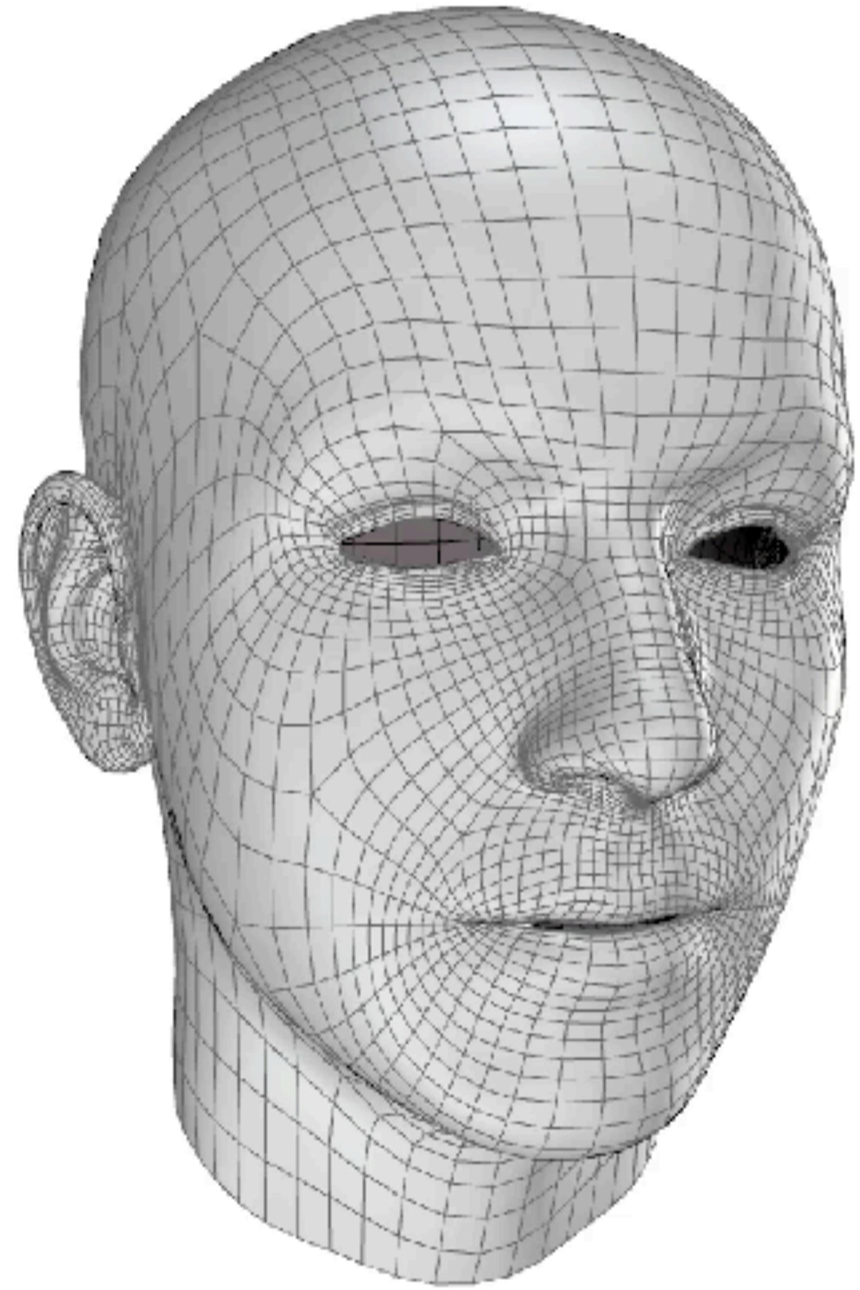
tracking

goal

Performance-Based Facial Tracking

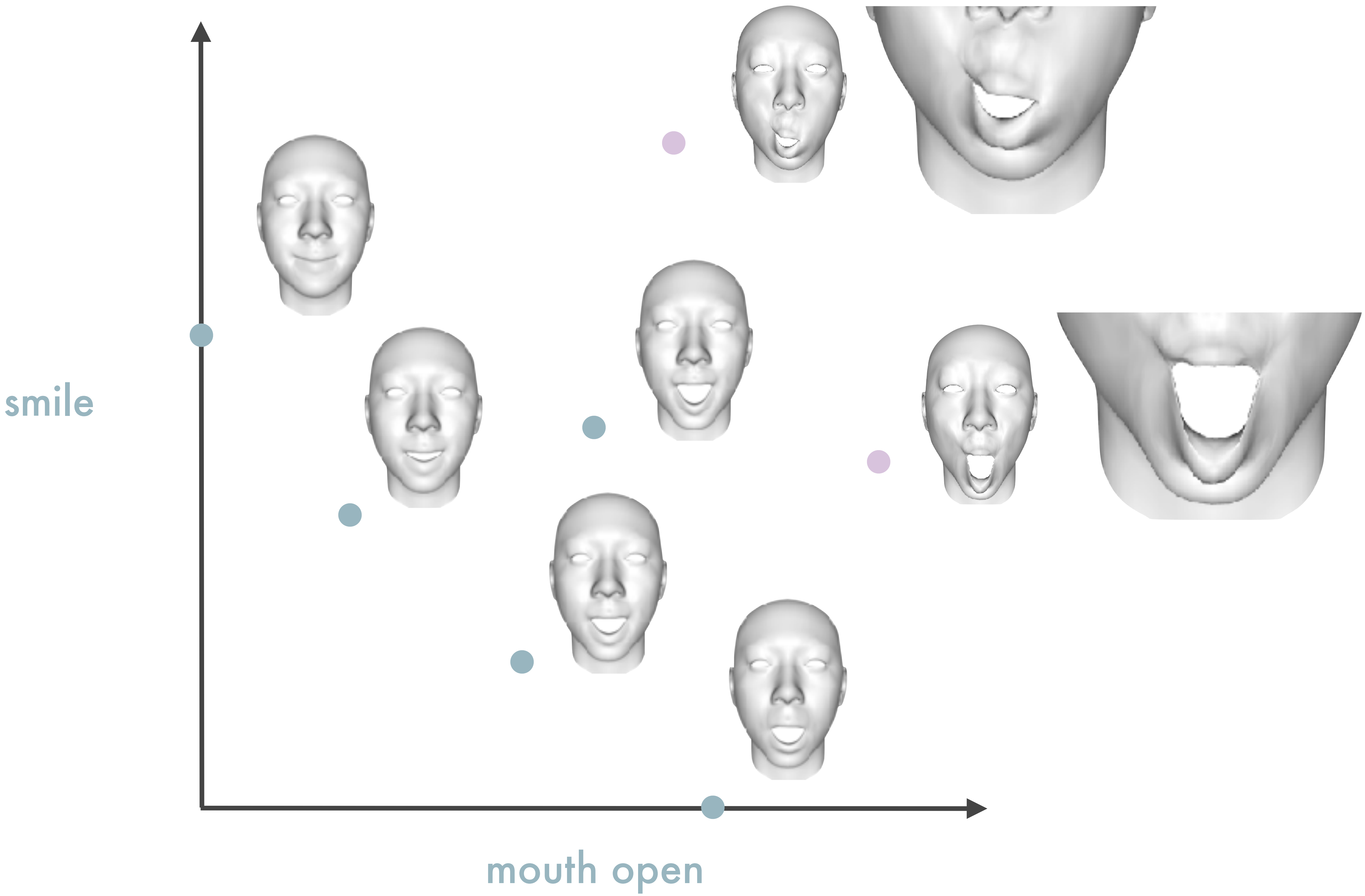


Animation as Prior

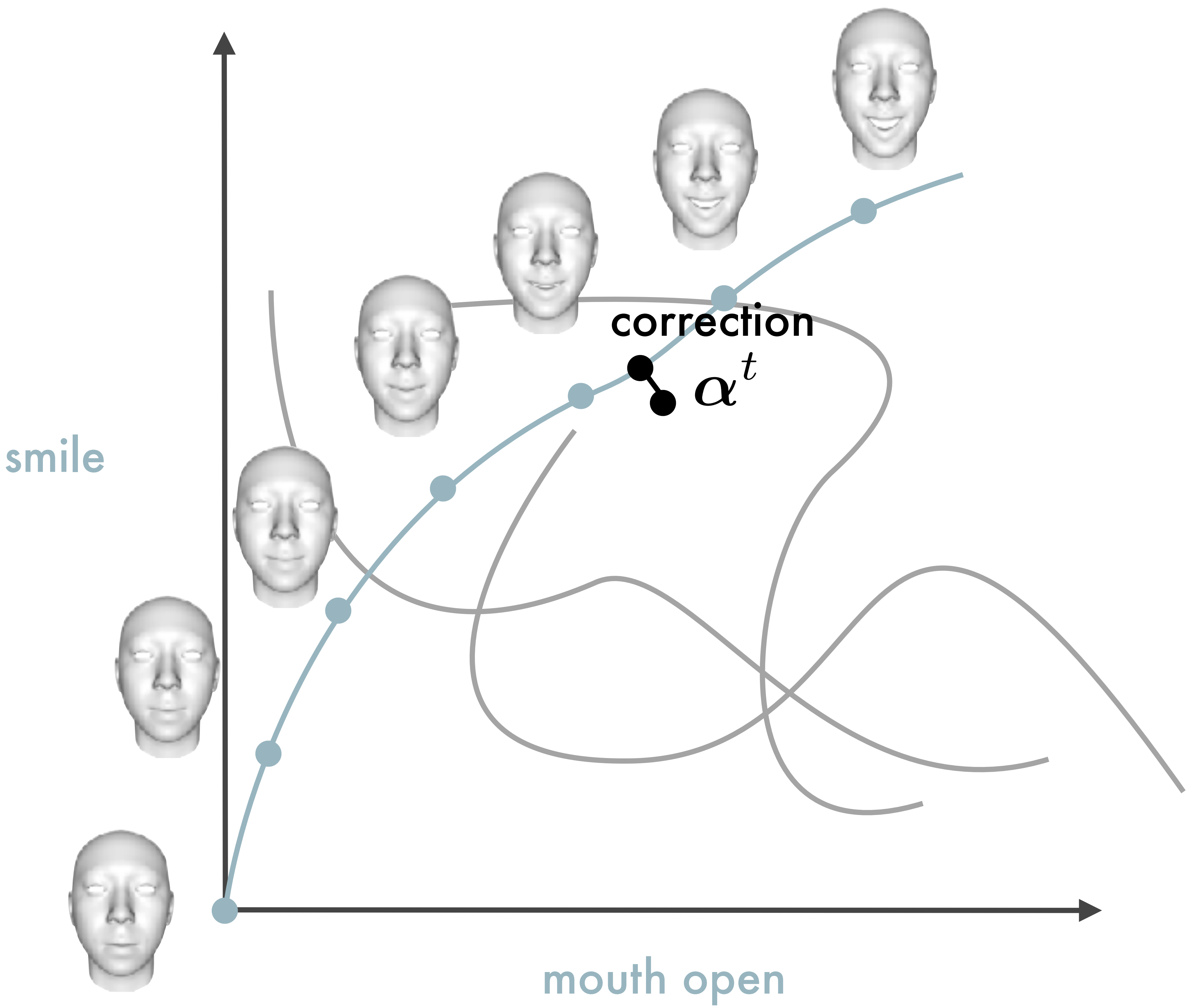


reference video → artist → 9500 frames

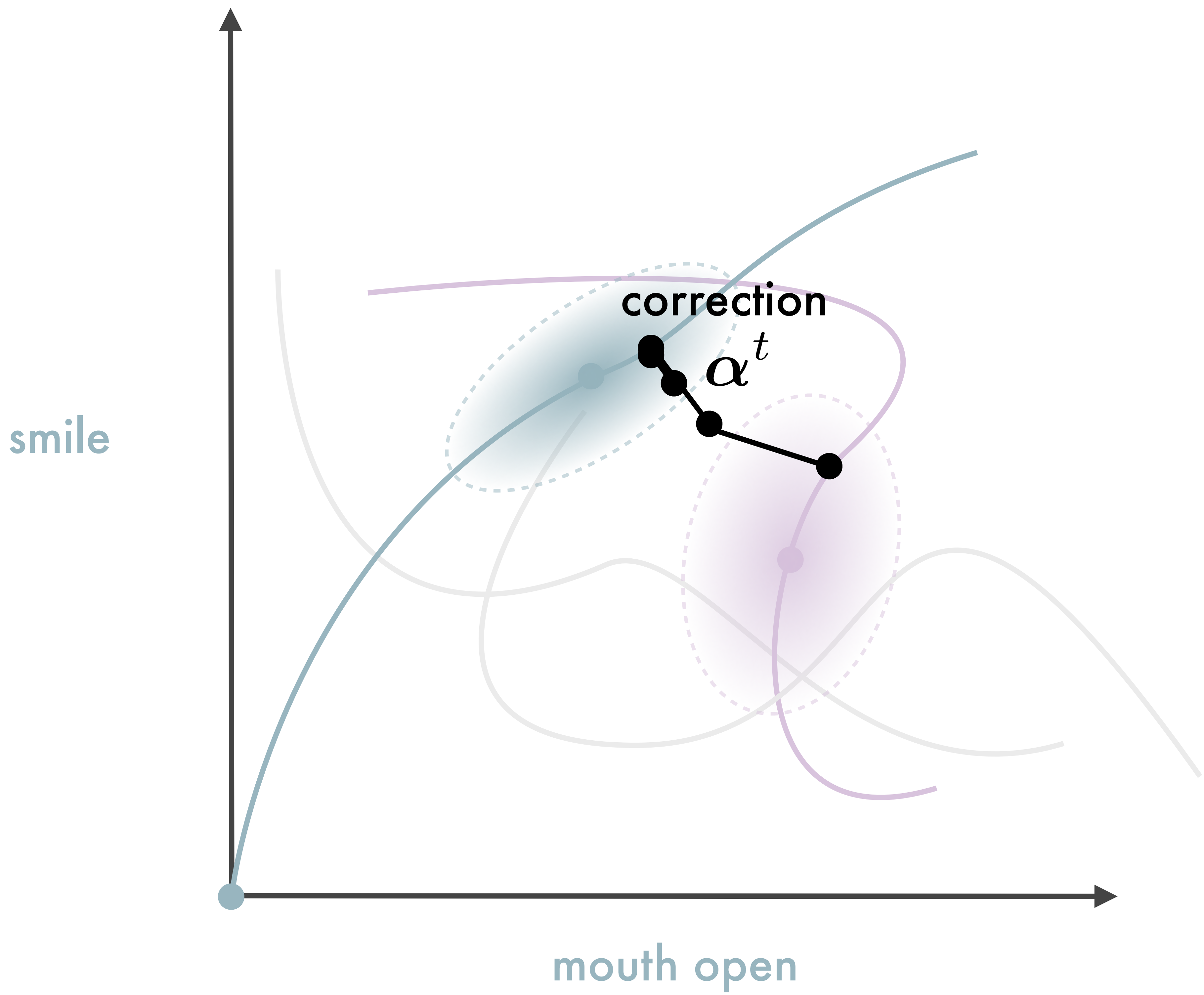
N-Dim Expression Space



Animation Manifold

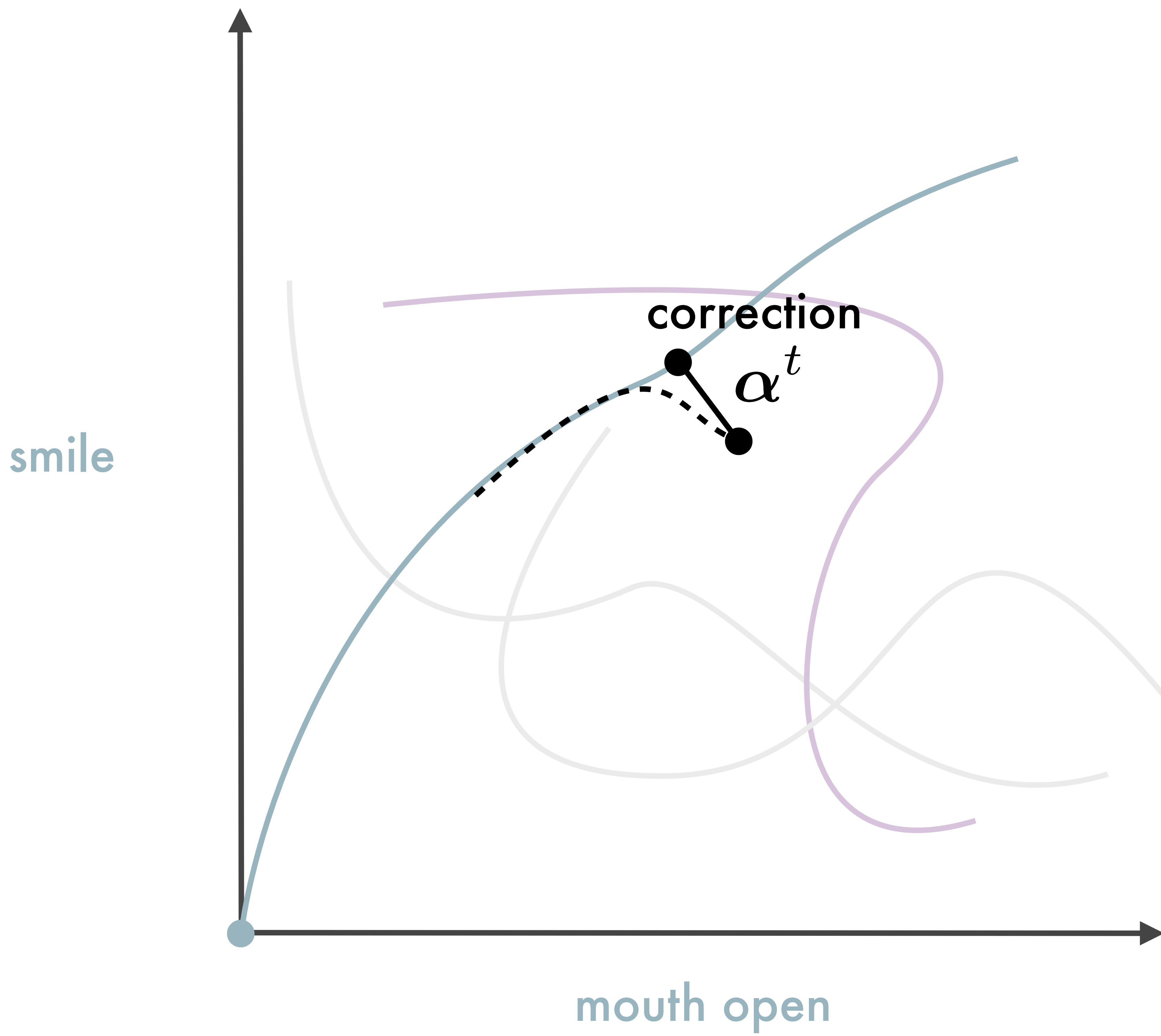


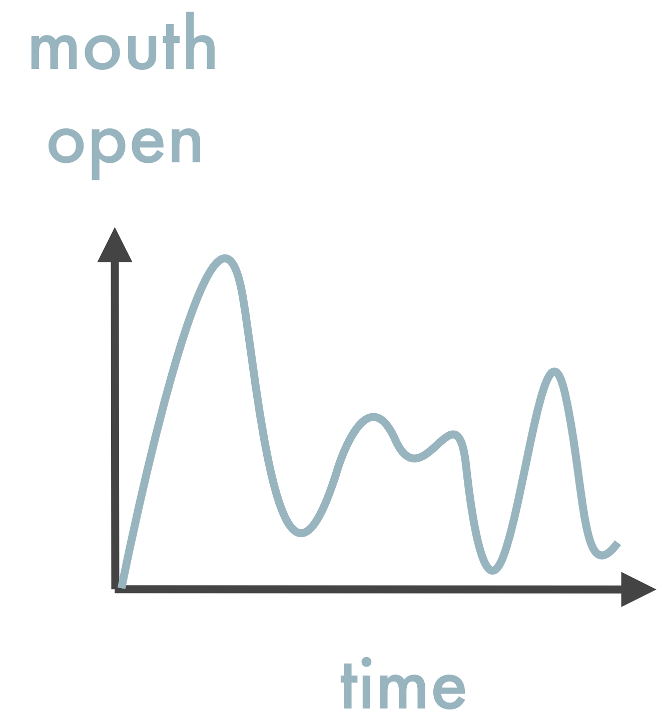
Probabilistic Animation Prior



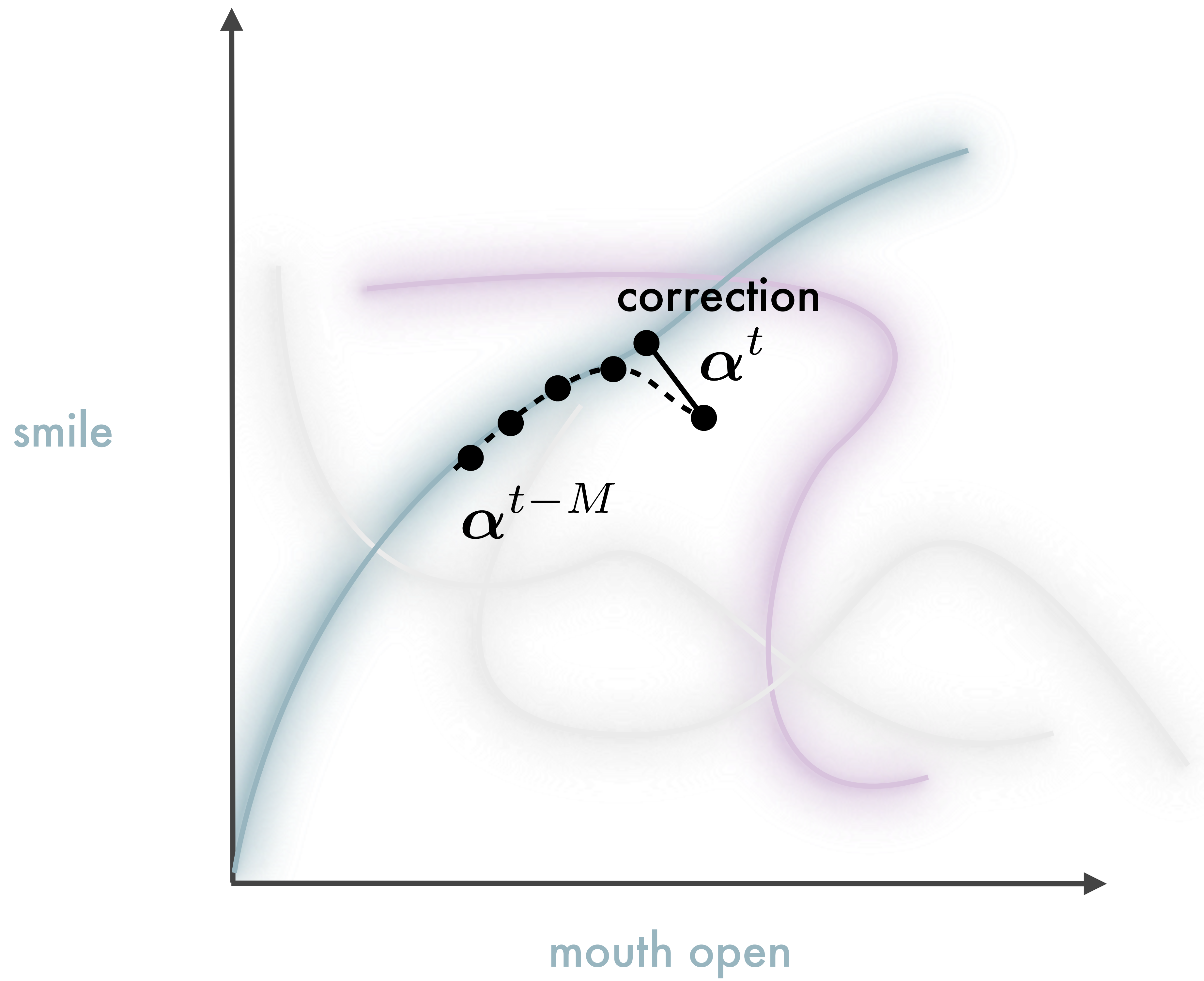
Lau et al. 2009

Probabilistic Animation Prior

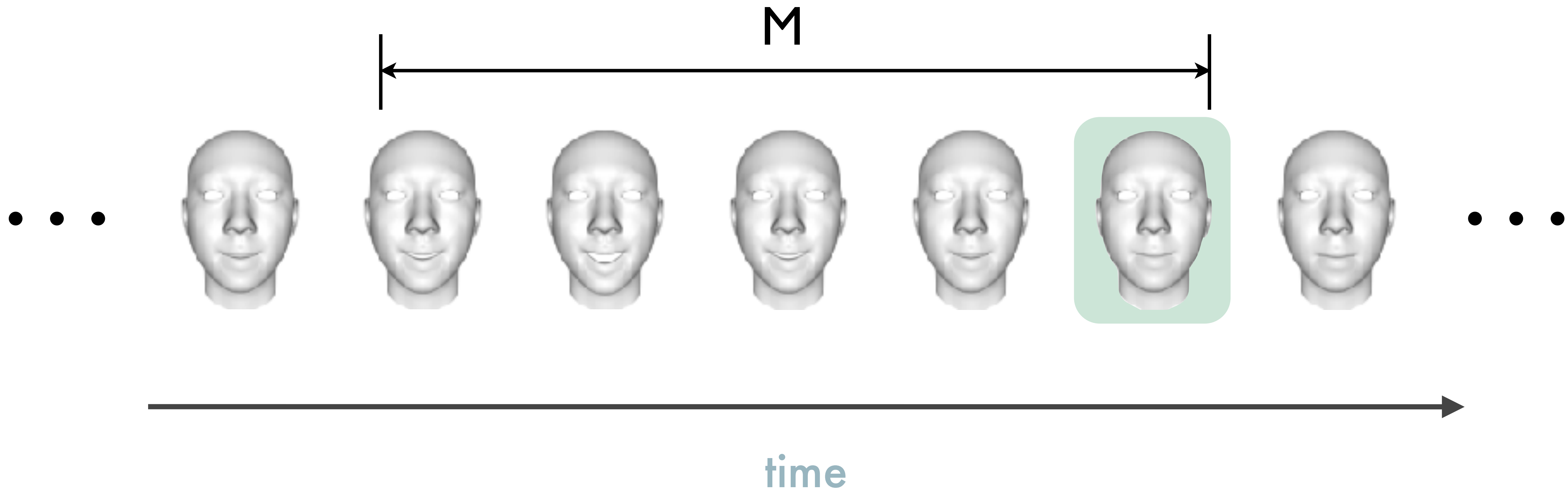




Probabilistic Animation Prior



Temporal Joint Probabilistic Distribution



$$p(\boldsymbol{\alpha}^t, .., \boldsymbol{\alpha}^{t-M}) = \sum_{k=1}^{K} \pi_k \mathcal{N}(\boldsymbol{\alpha}^t, .., \boldsymbol{\alpha}^{t-M} | \boldsymbol{\mu}_k, C_k C_k^T + \sigma_k^2 I).$$

MPPCA model

weights

mean

principal components

Gaussian noise

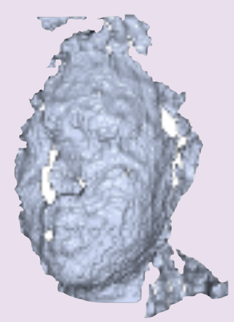
MAP Estimation

$$\boldsymbol{\alpha}^t = \arg\max_{\boldsymbol{\alpha}} p(\boldsymbol{\alpha} | D, \boldsymbol{\alpha}^{t-1}, .., \boldsymbol{\alpha}^{t-M})$$

MPPCA

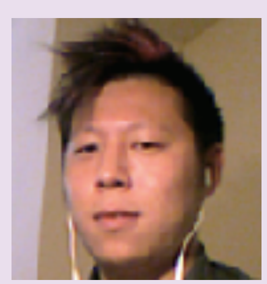
$$\approx \arg\max_{\boldsymbol{\alpha}} \underbrace{p(D|\boldsymbol{\alpha})}_{\text{likelihood}} \underbrace{p(\boldsymbol{\alpha}, \boldsymbol{\alpha}^{t-1}, .., \boldsymbol{\alpha}^{t-M})}_{\text{prior}}$$

geometry



$$p(G|\mathbf{x}) = \prod_{i=1}^{V} k_{geo} \exp(-\frac{||\mathbf{n}_i^T(\mathbf{v}_i - \mathbf{v}_i^*)||^2}{2\sigma_{\text{geo}}^2})$$

texture



$$p(I|\mathbf{x}) = \prod_{i=1}^{V} k_{im} \exp(-\frac{||\nabla I_i^T(\mathbf{p}_i - \mathbf{p}_i^*)||^2}{2\sigma_{\text{im}}^2})$$

ILM's Kinect Monster Mirror

Fast **Calibration**

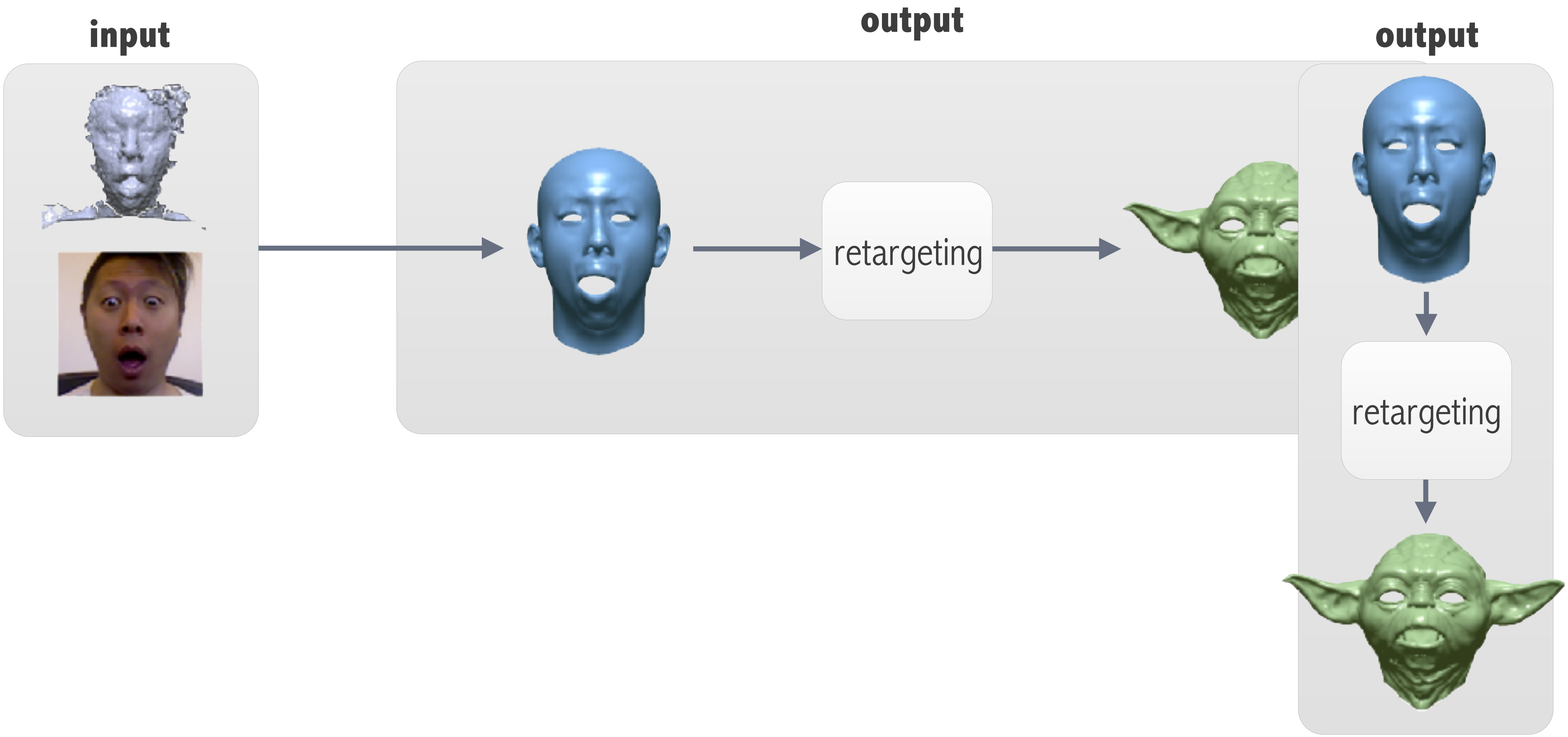
Li et al. SIGGRAPH 2013

Facial Performance Capture

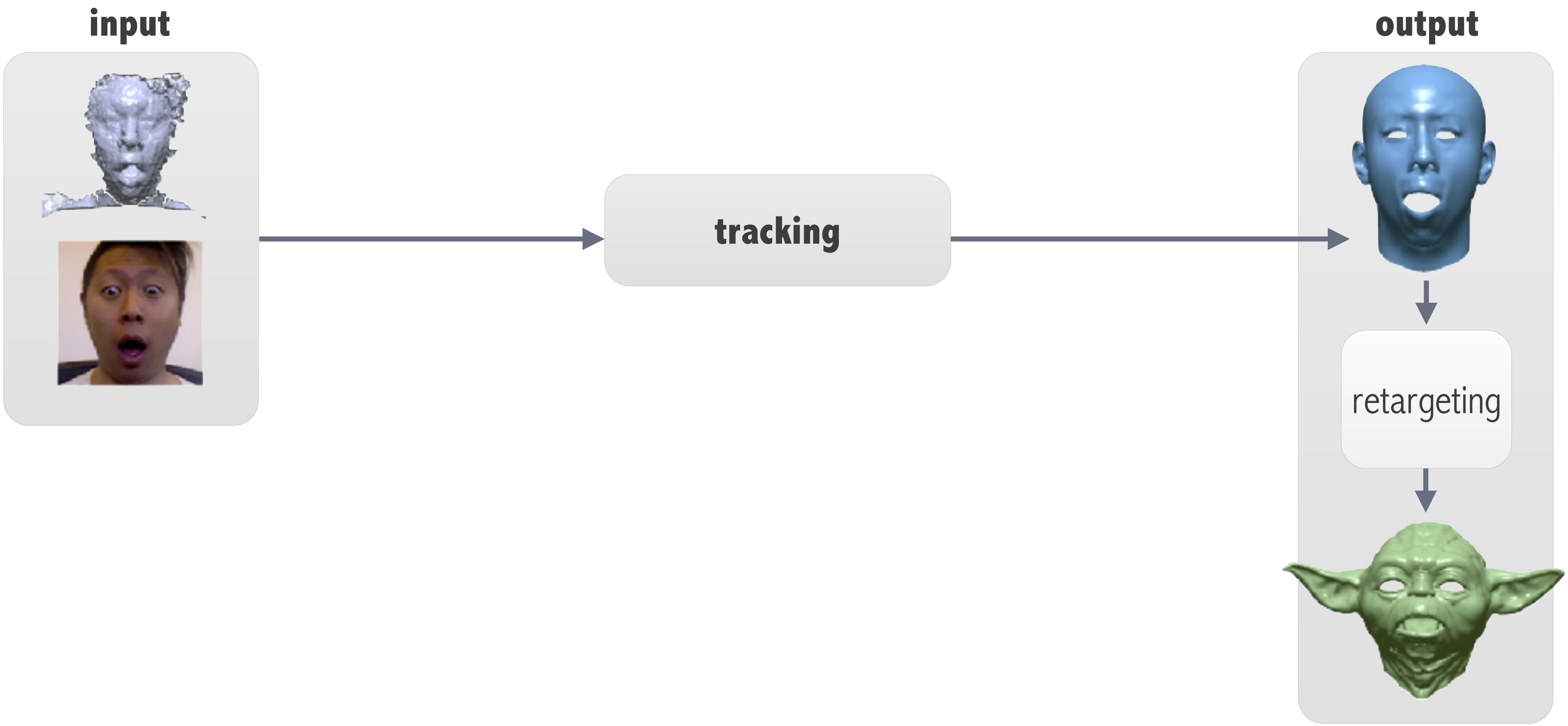
Li et al. SIGGRAPH 2013

Pipeline

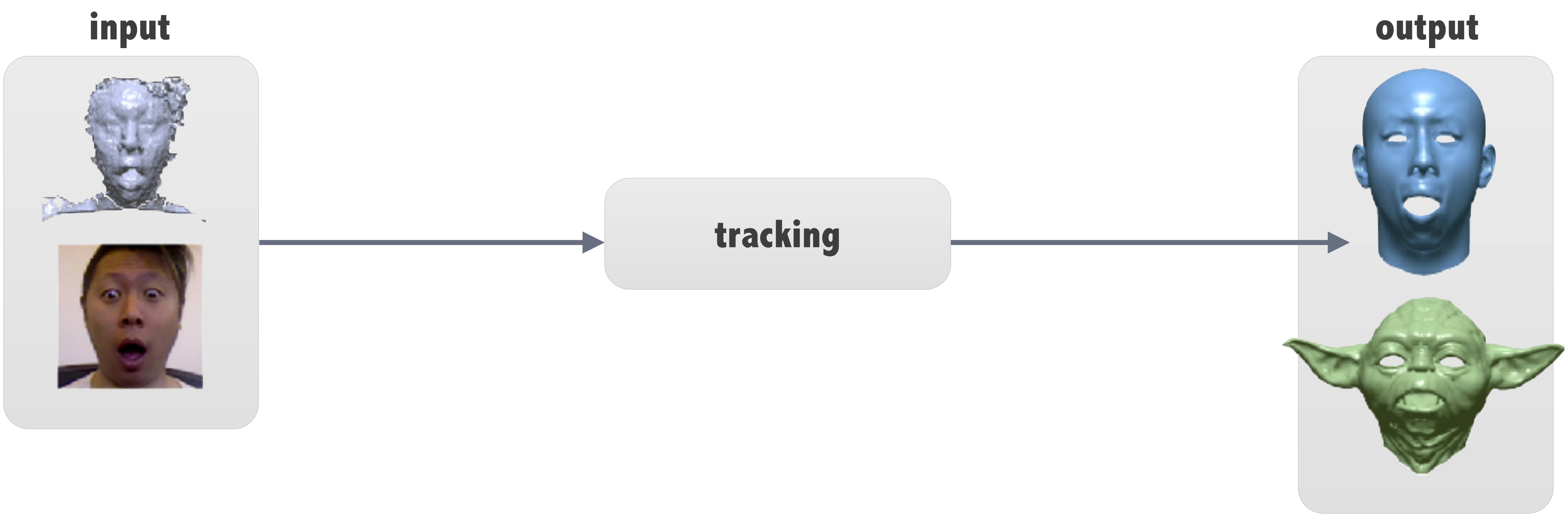
Pipeline Overview



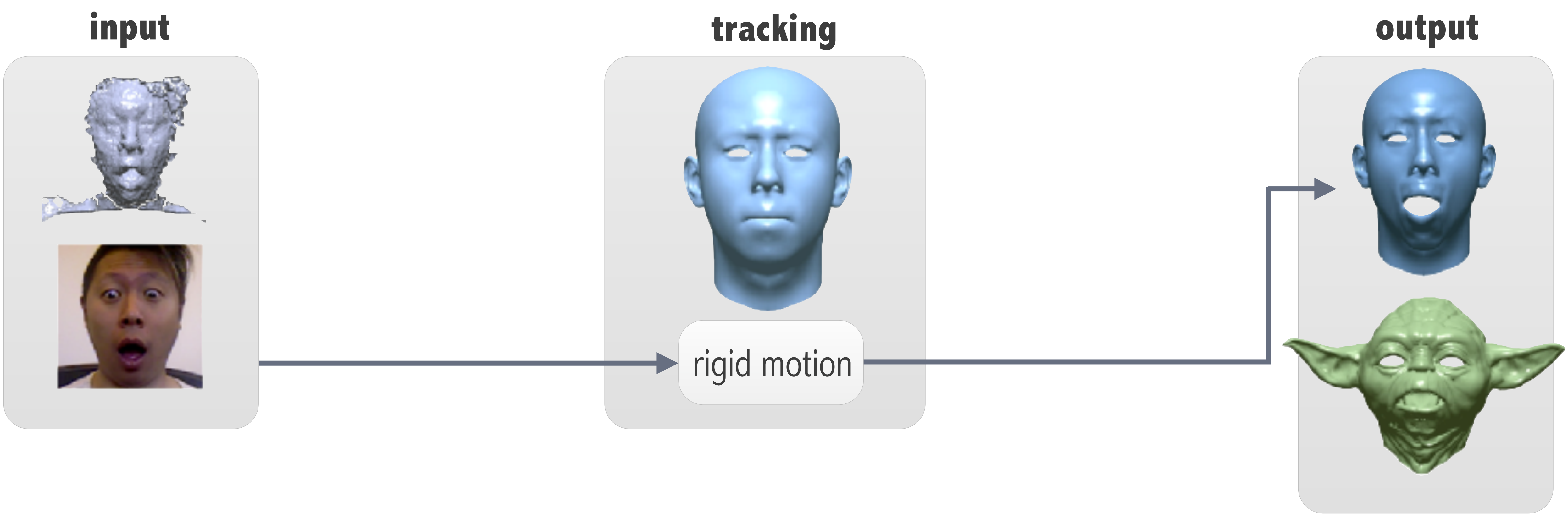
Pipeline Overview



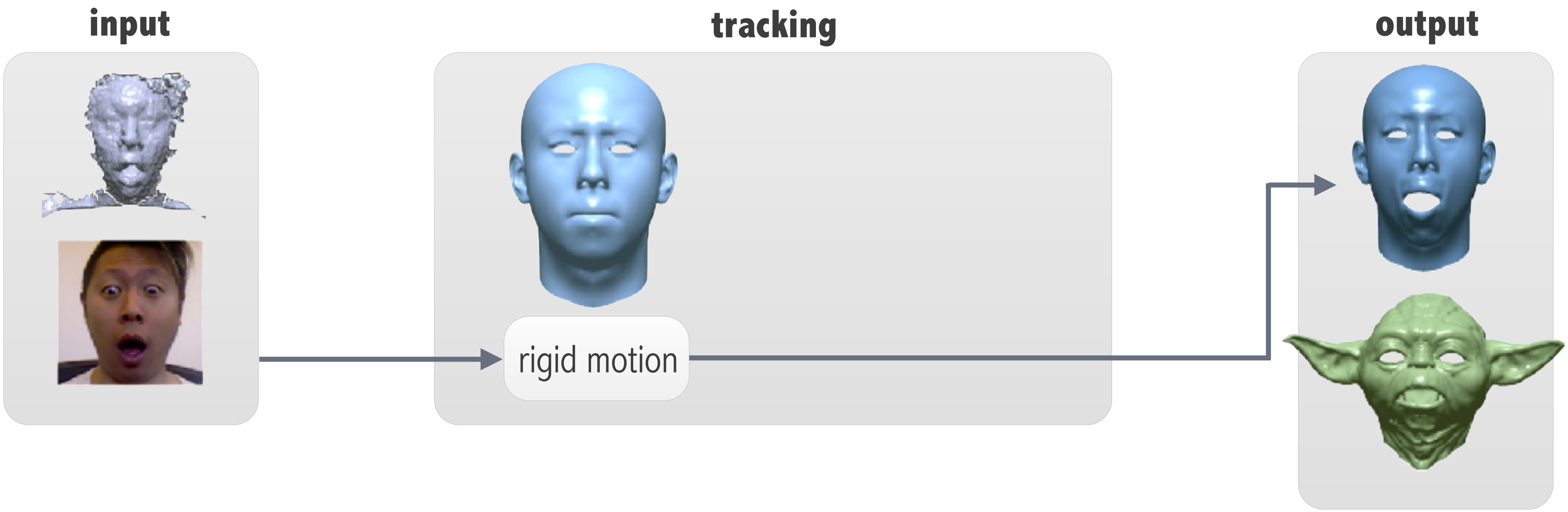
Pipeline Overview



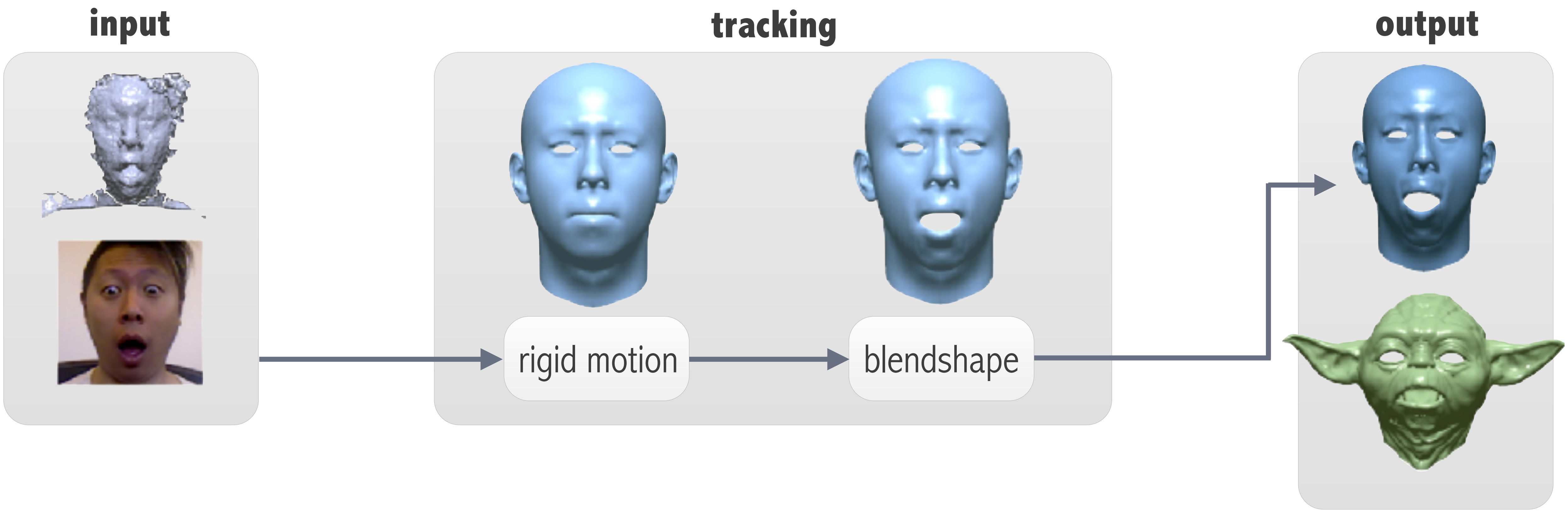
Pipeline Overview



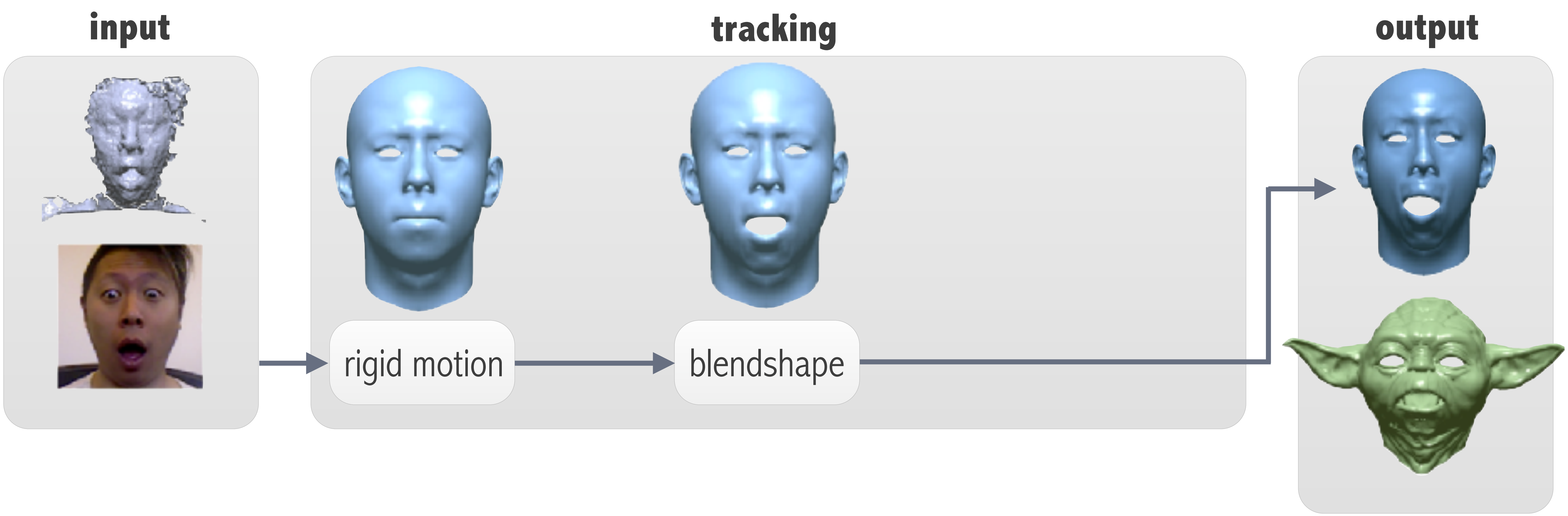
Pipeline Overview



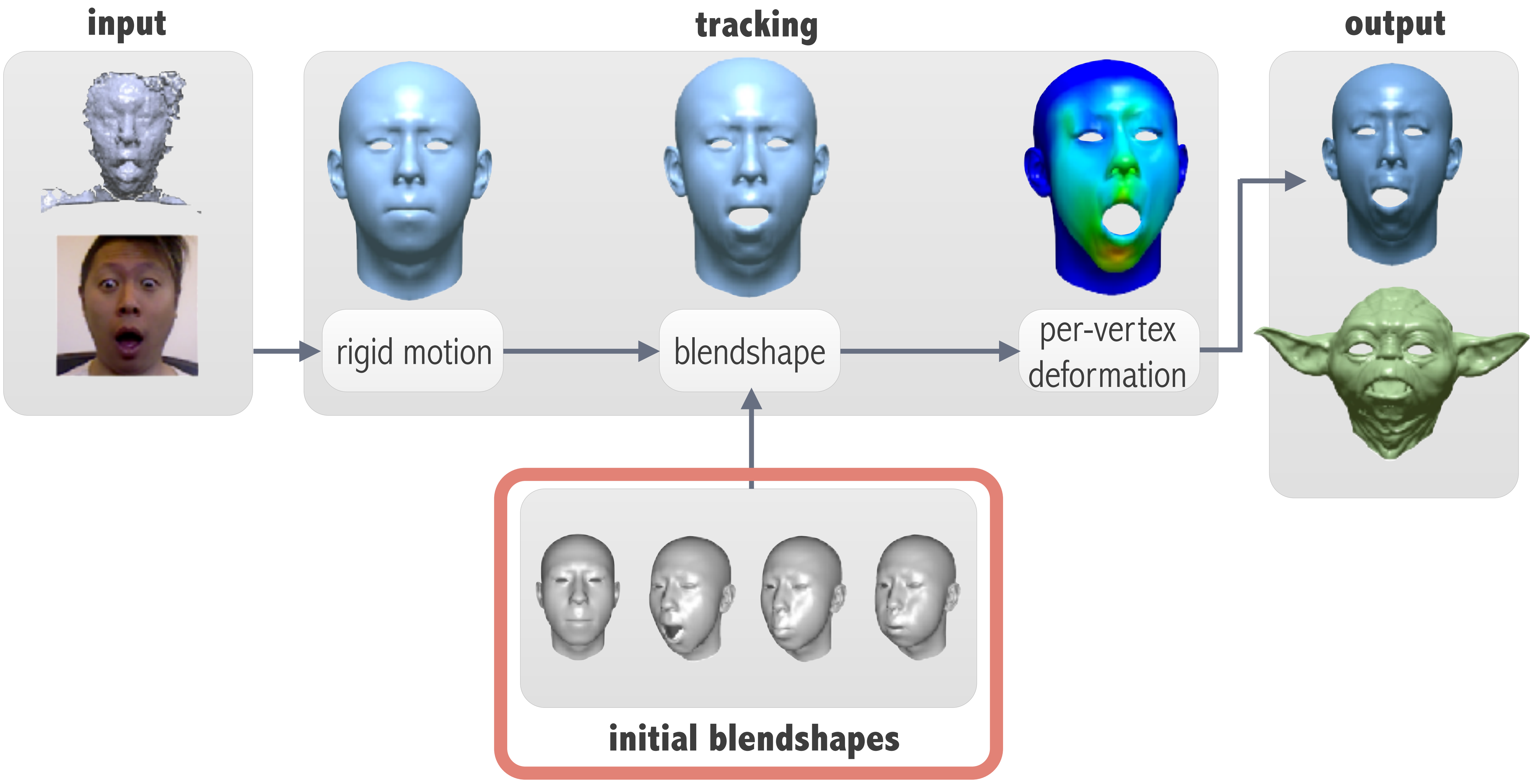
Pipeline Overview



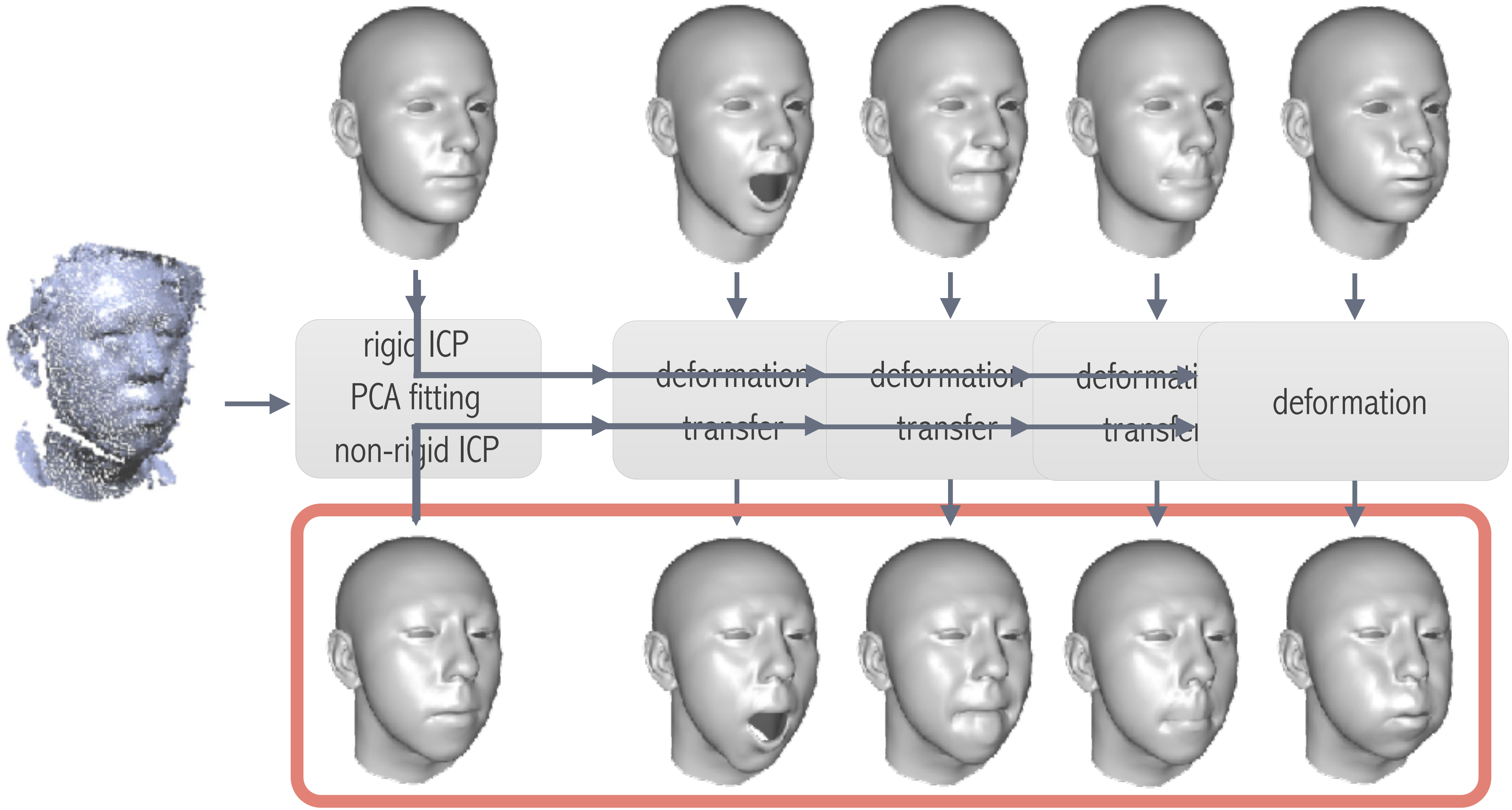
Pipeline Overview



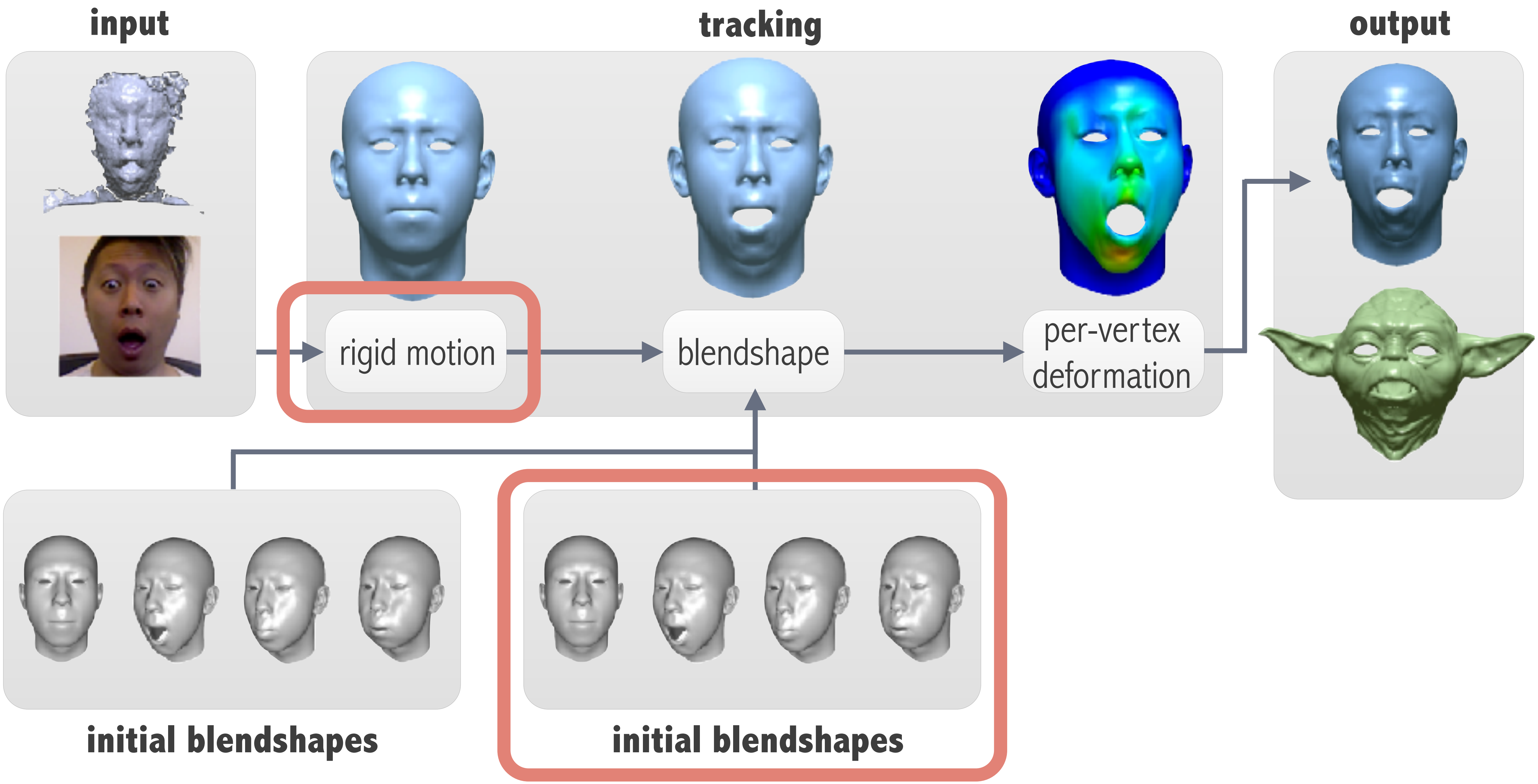
Pipeline Overview



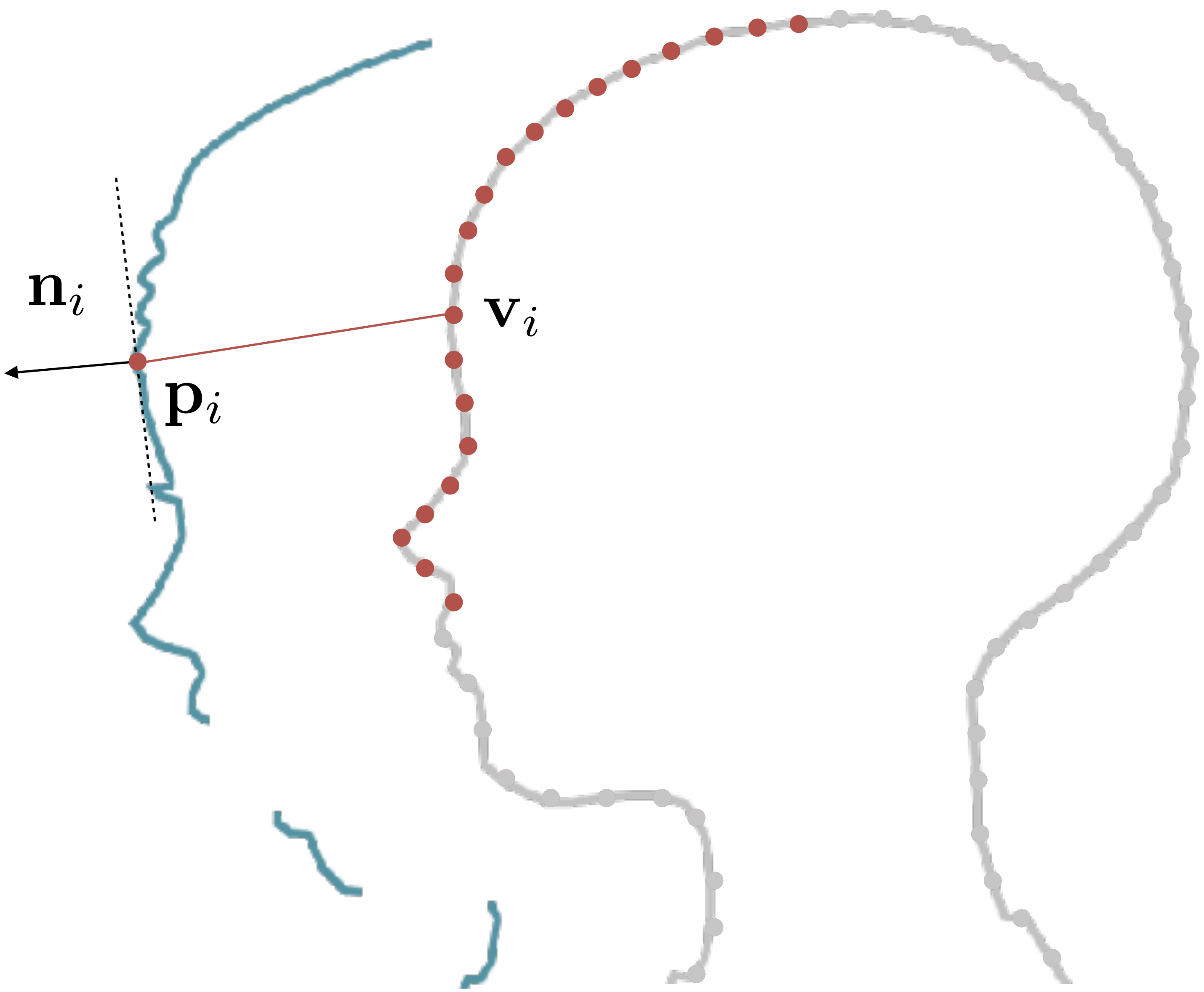
Building Initial Blendshape Model



Pipeline Overview



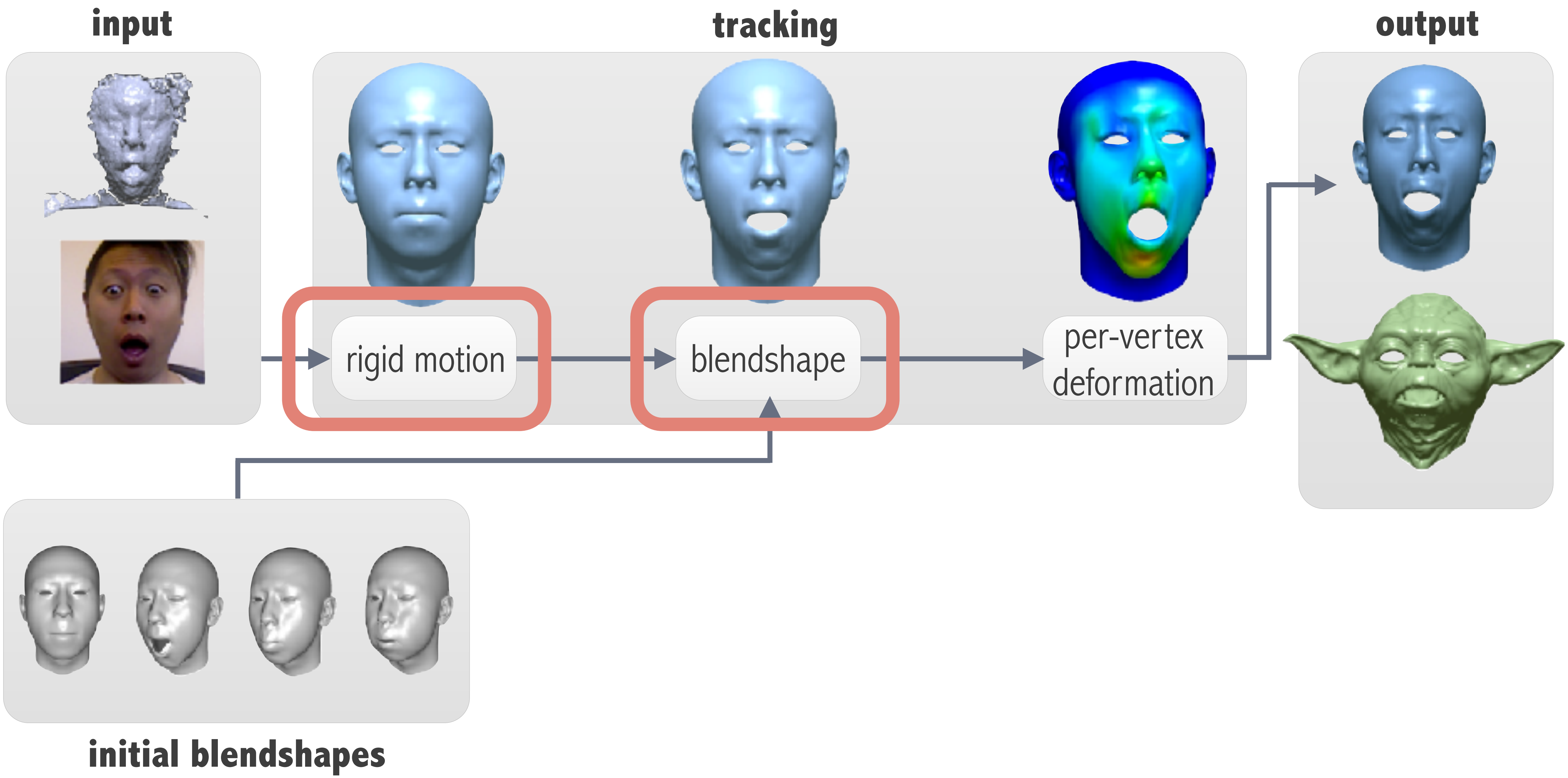
Rigid Motion Tracking



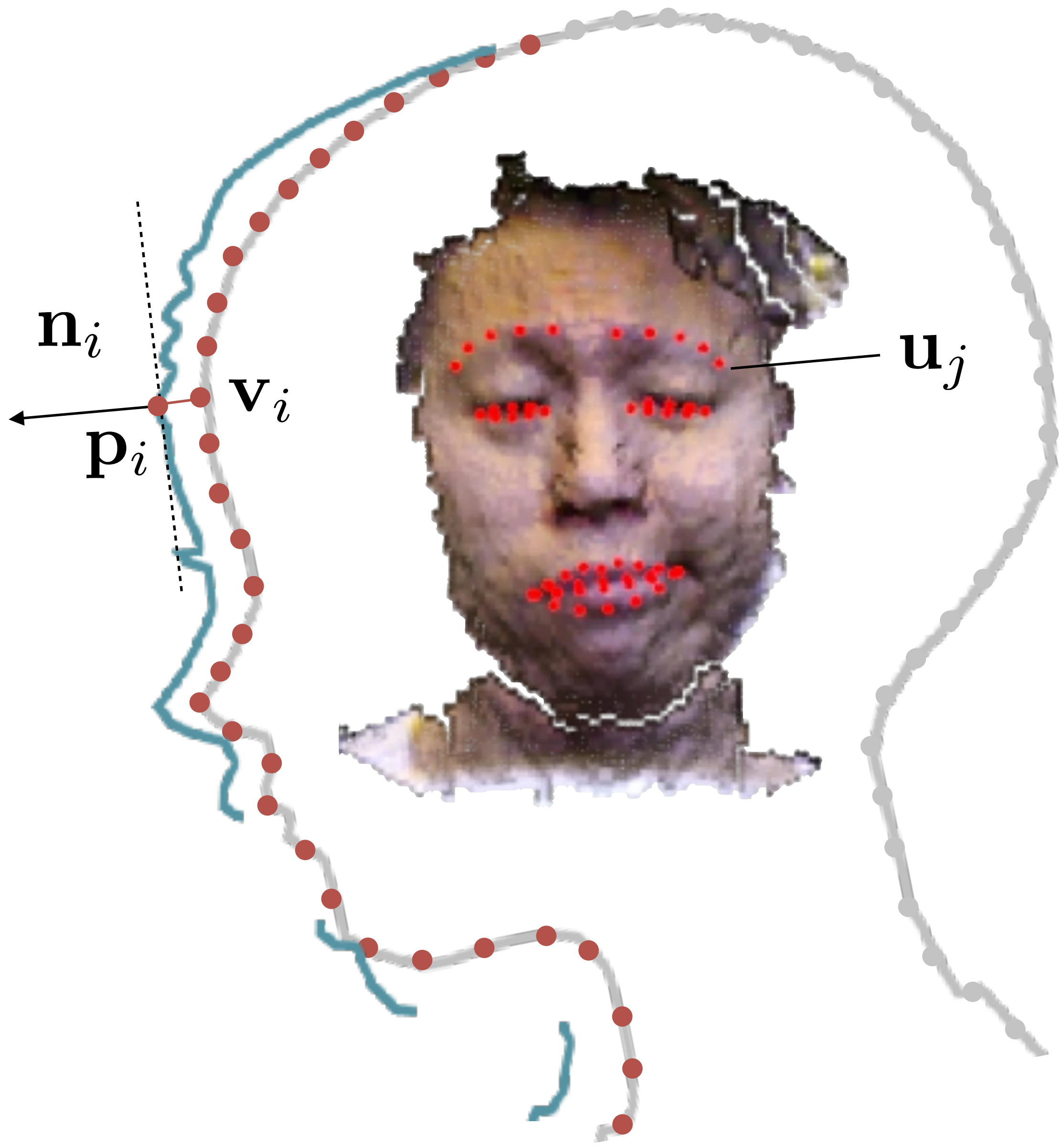
$$c_i^{\mathrm{S}}(\mathbf{R},\mathbf{t}) = \mathbf{n}_i^{\top}(\mathbf{v}_i(\mathbf{R},\mathbf{t}) - \mathbf{p}_i)$$

$$E_{\text{rigid}} = \min_{\mathbf{R},\mathbf{t}} \sum_i c_i^{\mathrm{S}}(\mathbf{R},\mathbf{t})$$

Rigid Motion Tracking



Blendshape Tracking



$$\mathbf{v}_i(\mathbf{x}) = \mathbf{v}_i^{(0)} + \sum_l \mathbf{v}_i^{(l)} x_l$$

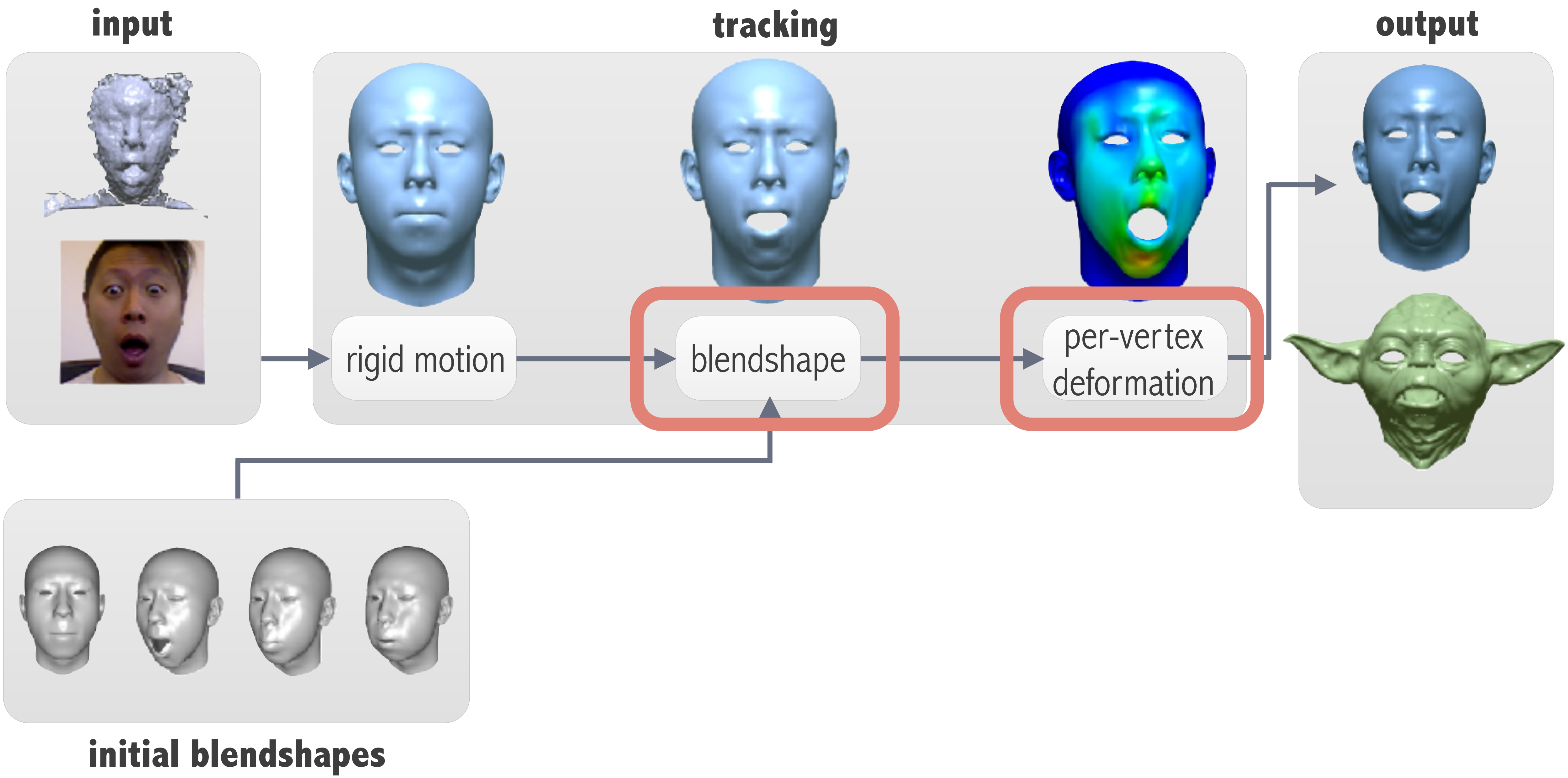
$$c_i^{\mathrm{S}}(\mathbf{x}) = \mathbf{n}_i^\top (\mathbf{v}_i(\mathbf{x}) - \mathbf{p}_i)$$

$$\mathbf{c}_j^{\mathrm{F}}(\mathbf{x}) = \mathbf{H}_j(\mathbf{u}_j)\ \mathbf{P}\ \mathbf{v}_j(\mathbf{x})$$

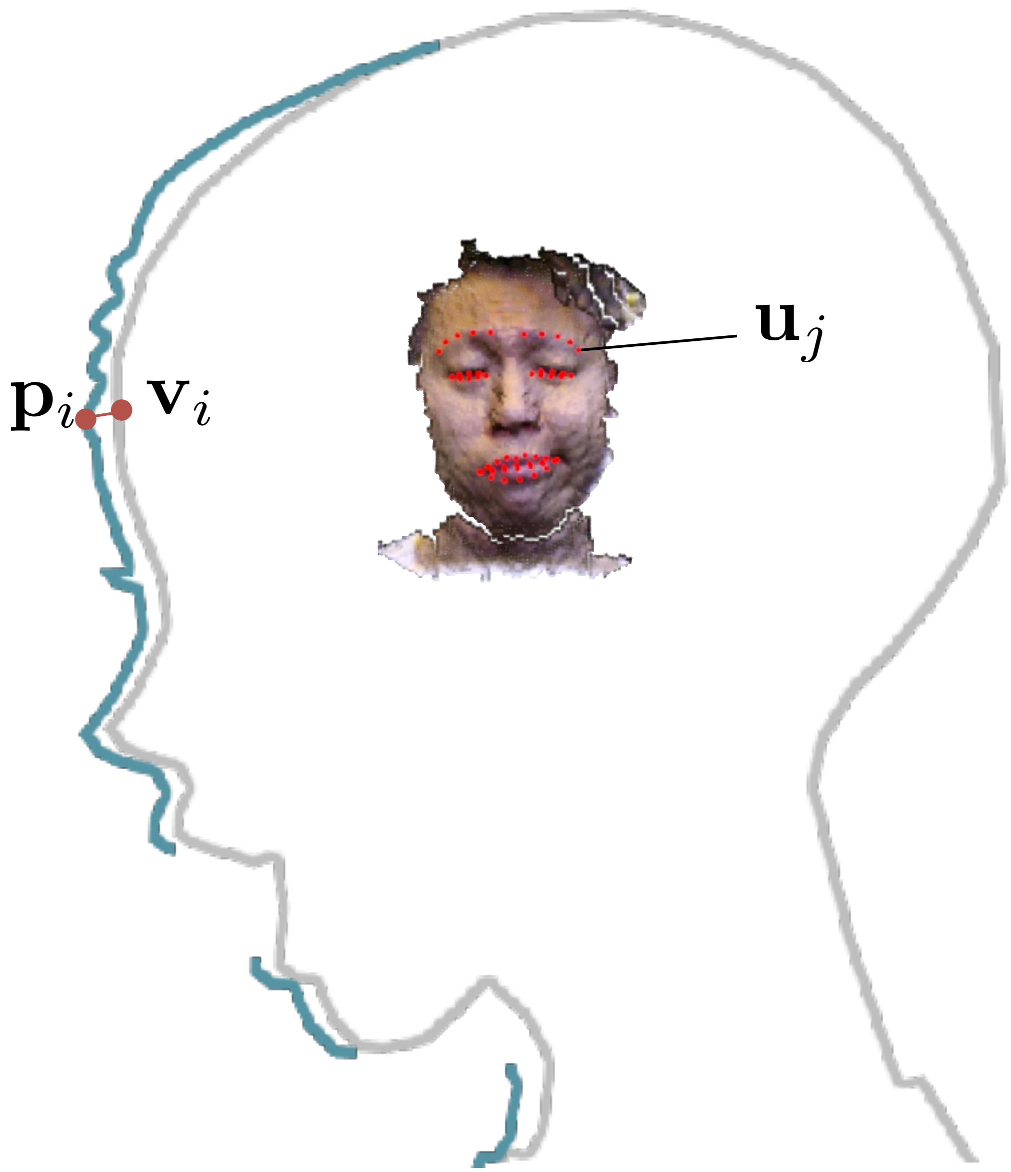
$$E_{\mathrm{bs}} = \min_{\mathbf{x}} \sum_i (c_i^{\mathrm{S}}(\mathbf{x}))^2 + w \sum_j \|\mathbf{c}_j^{\mathrm{F}}(\mathbf{x})\|^2$$

$$x_l \in [0, 1]$$

Pipeline Overview



Per-Vertex Deformation



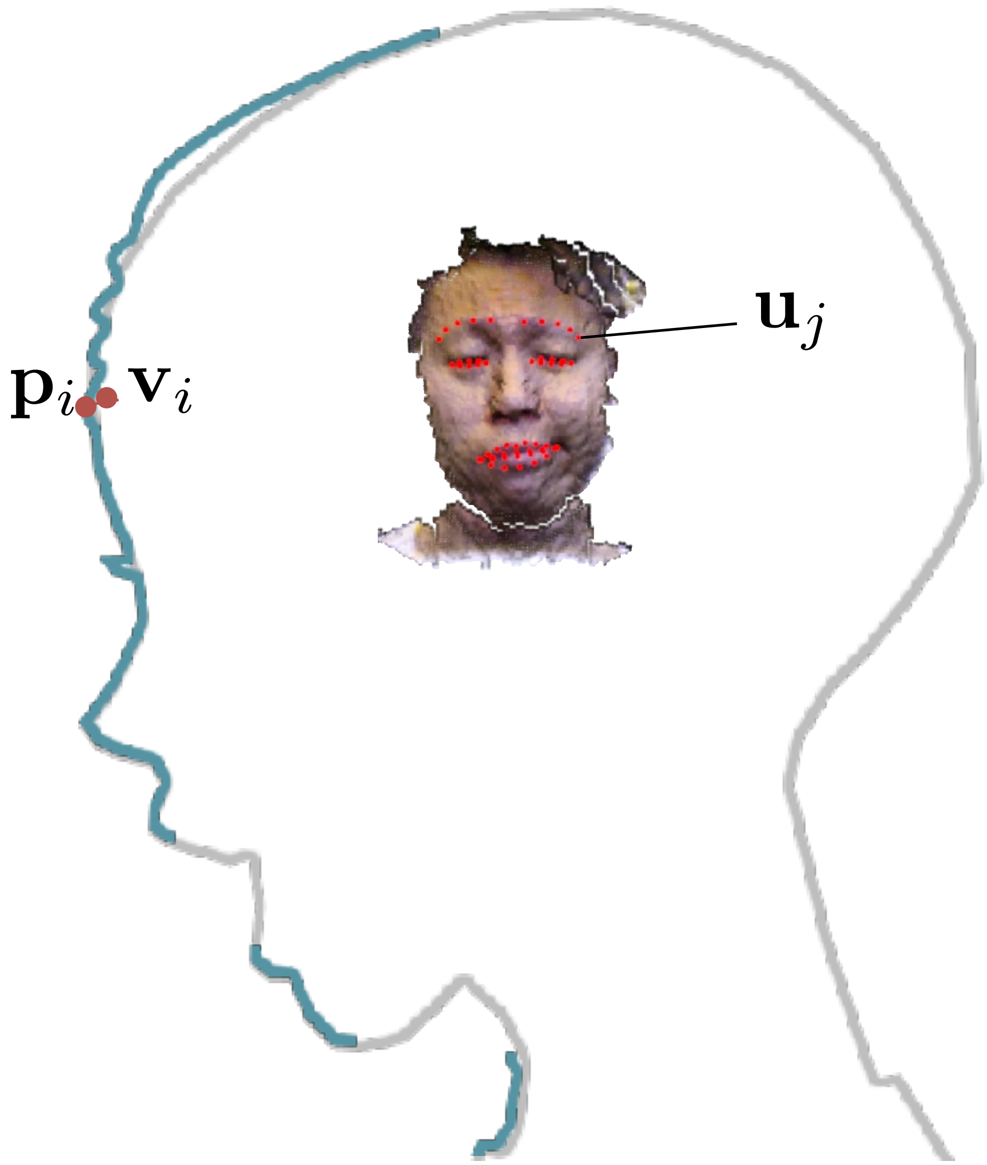
$$\mathbf{c}_i^{\mathrm{P}}(\Delta\mathbf{v}_i) = (\mathbf{p}_i - \mathbf{v}_i) - \Delta\mathbf{v}_i$$

$$\mathbf{c}_j^{\mathrm{W}}(\Delta\mathbf{v}_j) = \mathbf{H}_j(\mathbf{u}_j)\,\mathbf{P}\,\Delta\mathbf{v}_j$$

$$\mathbf{c}^{\mathrm{L}}(\Delta\mathbf{v}) = \mathbf{L}(\mathbf{b}_0)\,\Delta\mathbf{v}$$

$$\mathbf{G}\begin{bmatrix}\mathbf{I}\\ \mathbf{Q}\\ \mathbf{L}\end{bmatrix}\Delta\mathbf{v} = \mathbf{a}$$

Fast Laplacian Deformation



$$\mathbf{G}\begin{bmatrix}\mathbf{I}\\\mathbf{Q}\\\mathbf{L}\end{bmatrix}\Delta\mathbf{v} = \mathbf{a}$$

$$\mathbf{G}\;\mathbf{K}\;\Delta\mathbf{v} = \mathbf{a}$$

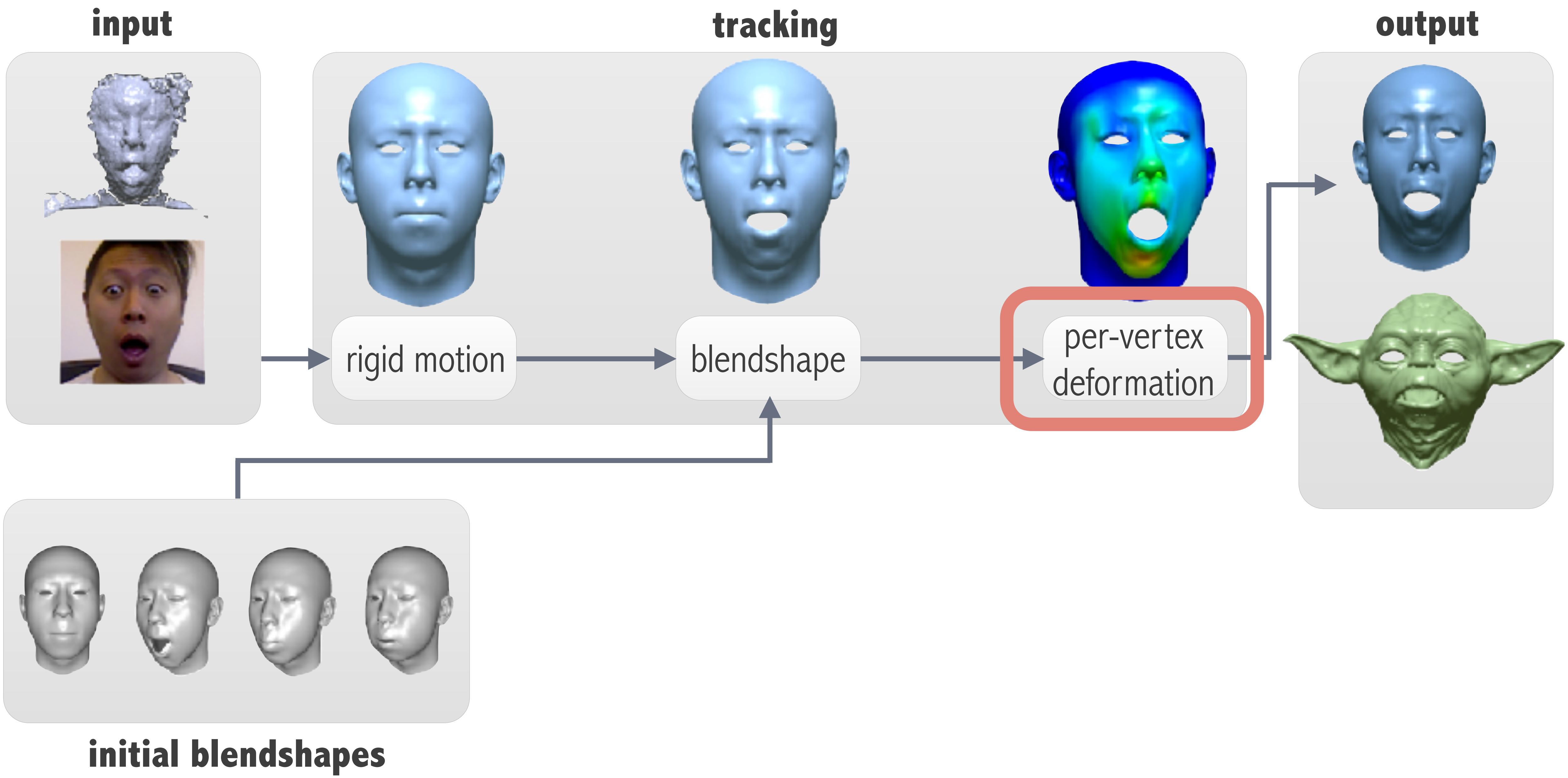
$$\Delta\mathbf{v} = \mathbf{K}^\top[\mathbf{K}\mathbf{K}^\top]^{-1}\mathbf{G}^{-1}\mathbf{a}$$

sparse
constant in time

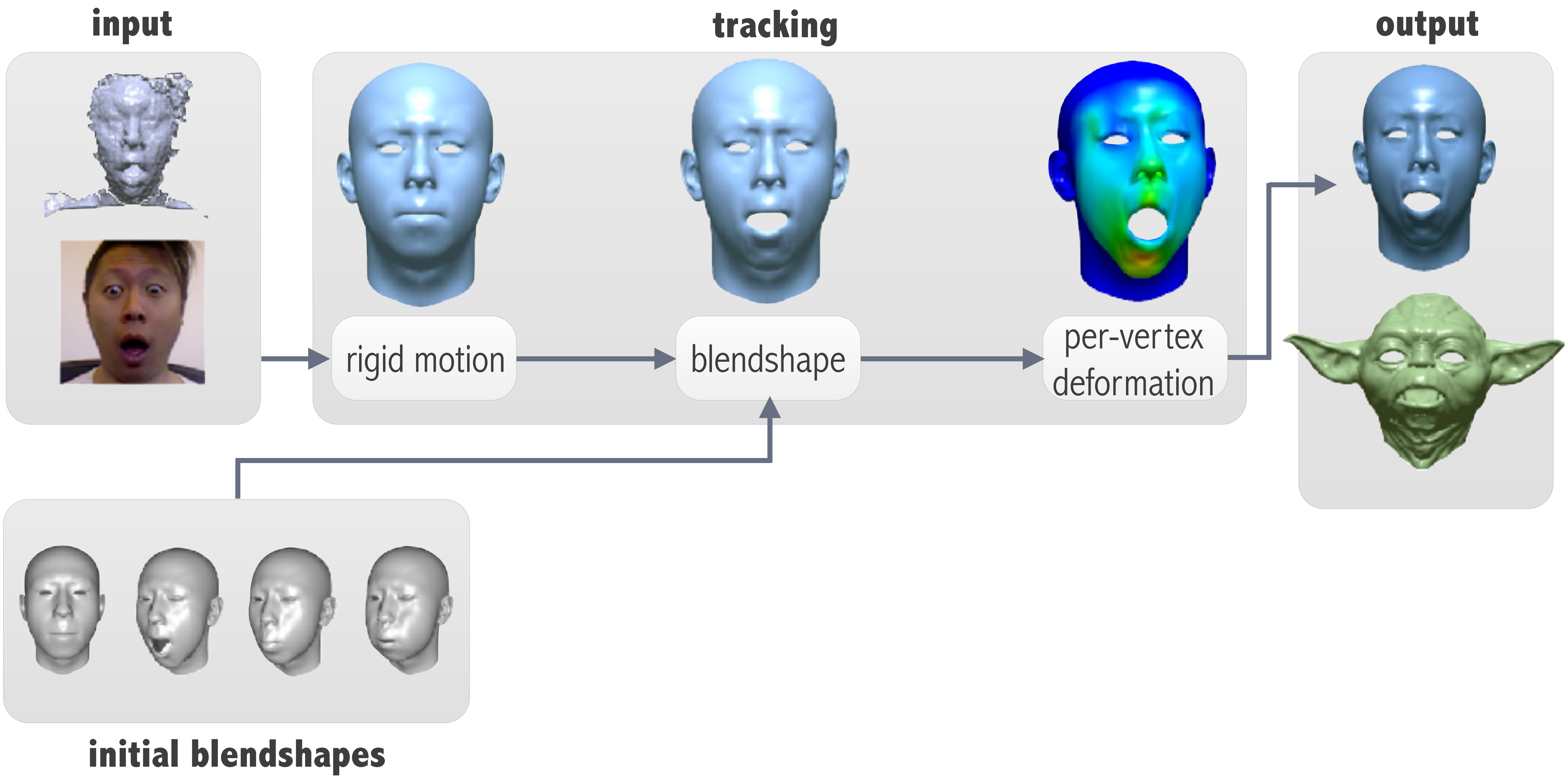
pre-factorized
constant in time

sparse
trivially inversed

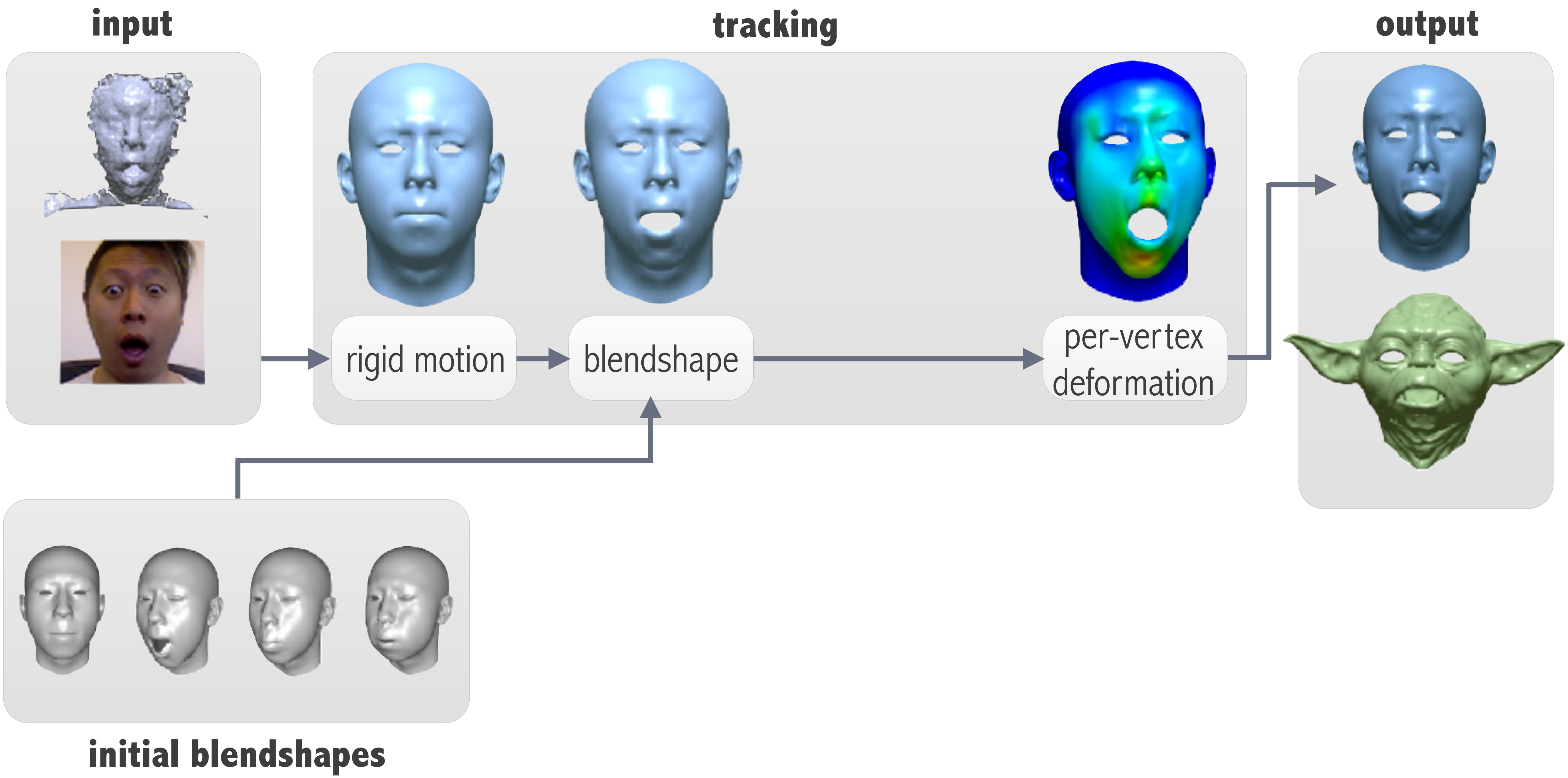
Pipeline Overview



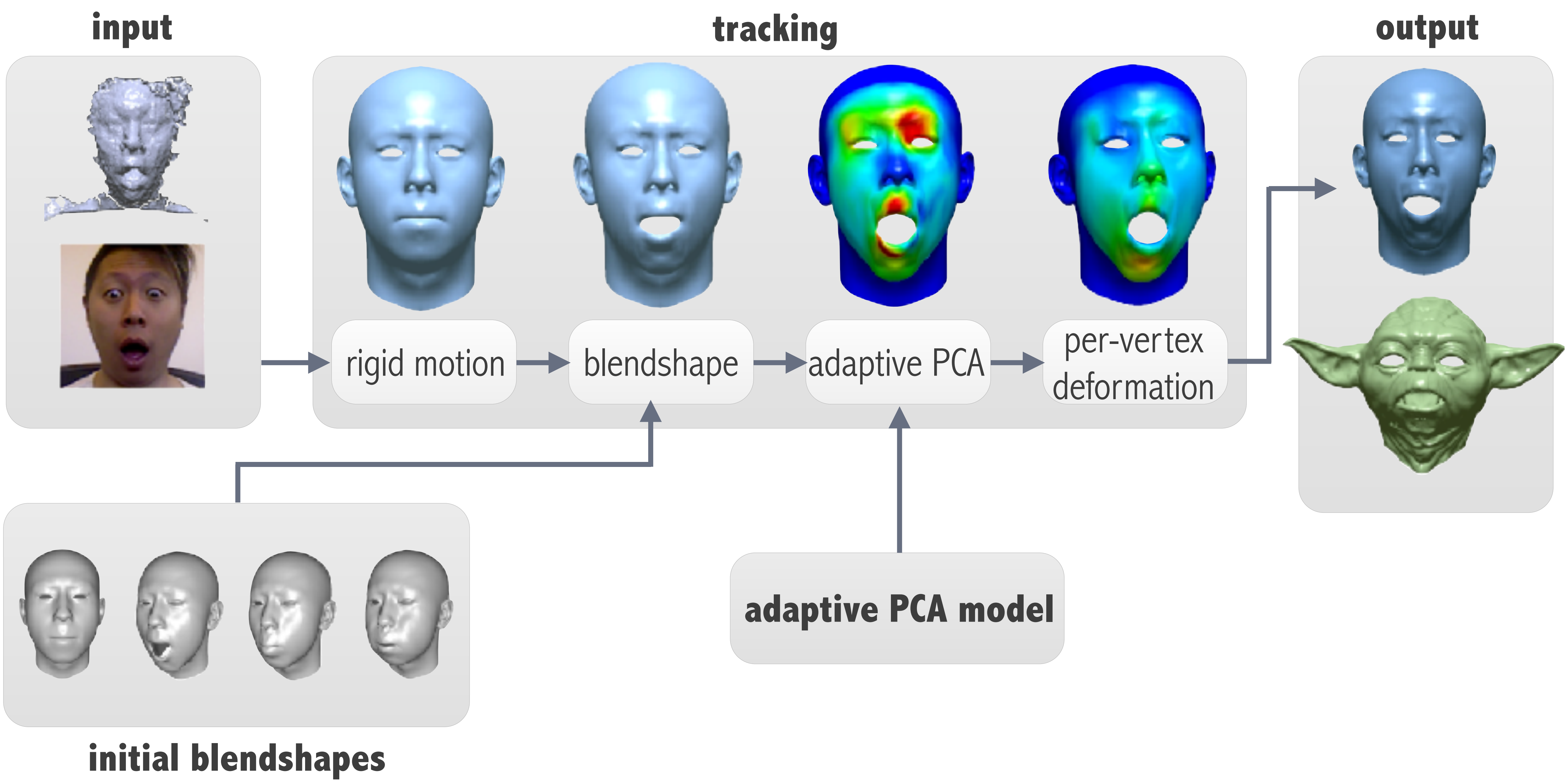
Pipeline Overview



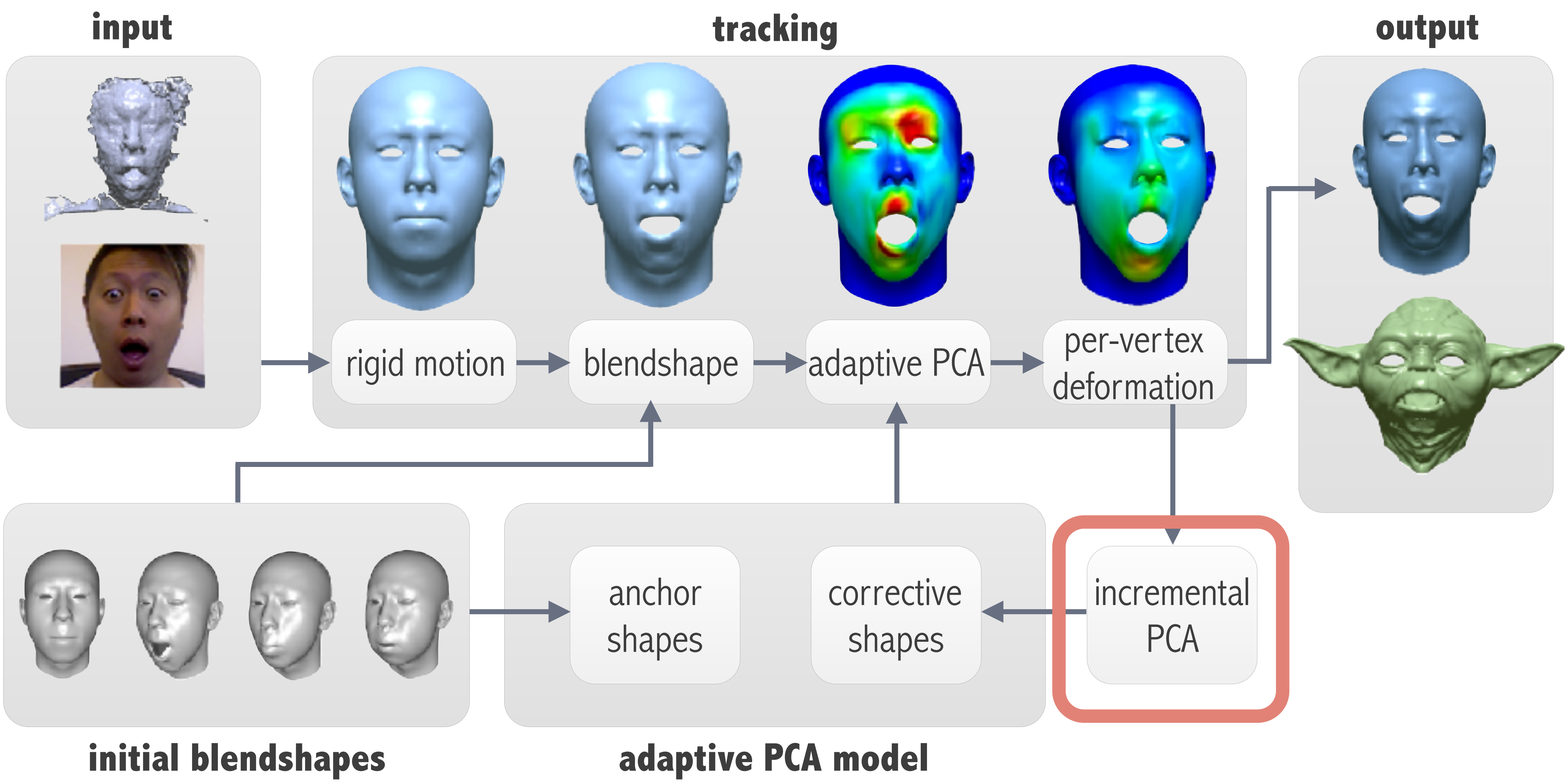
Pipeline Overview



Pipeline Overview



Pipeline Overview

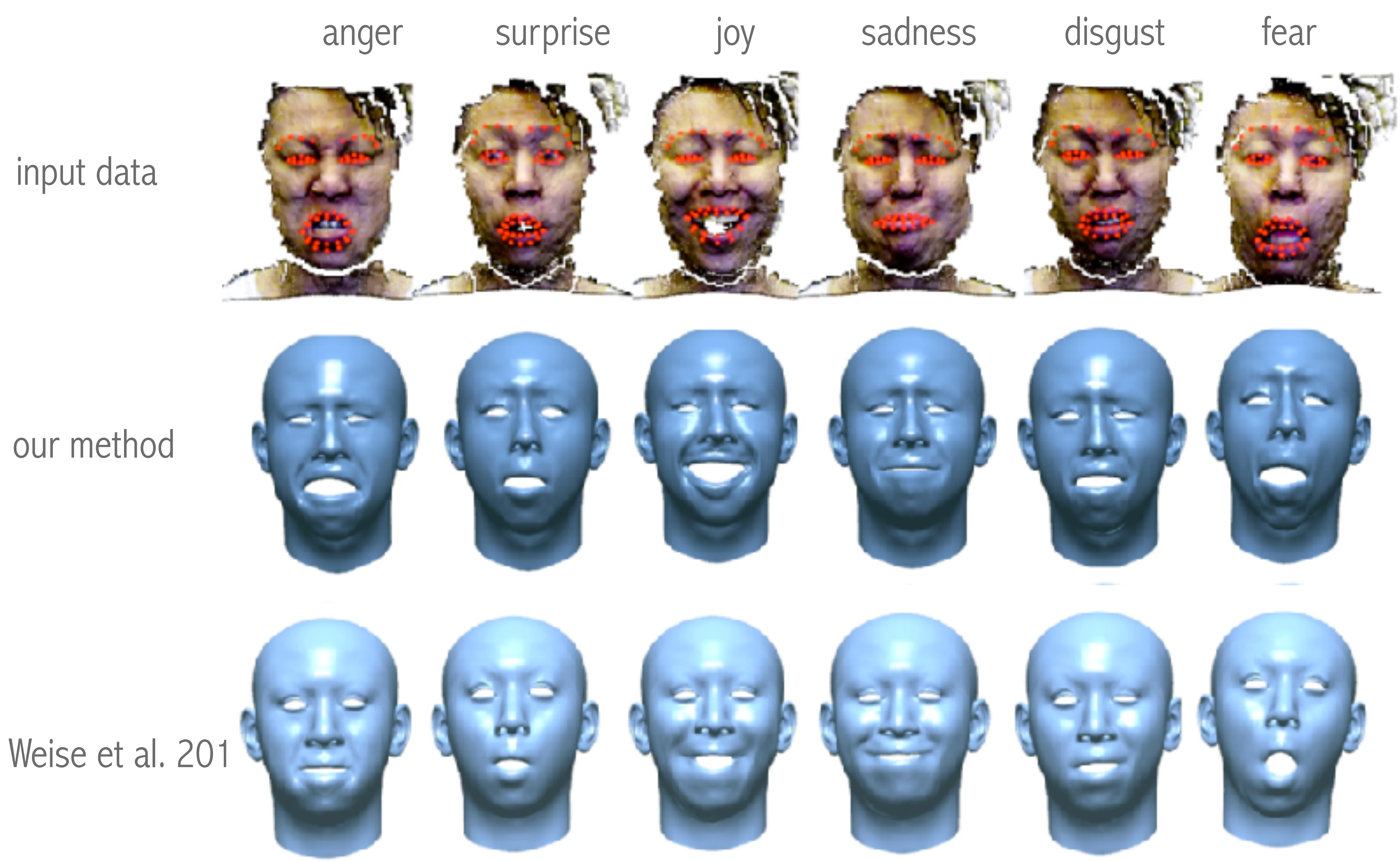


Tracking Comparison

depth map &
2D features

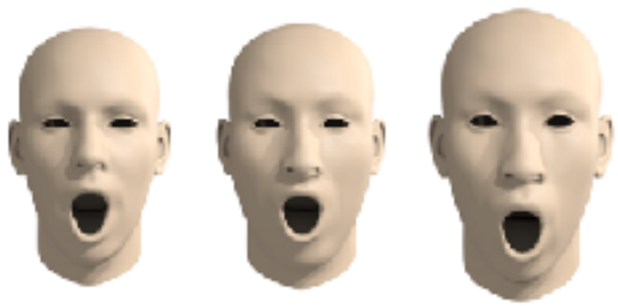
Tracking **Basic Emotions**

Li et al. SIGGRAPH 2013



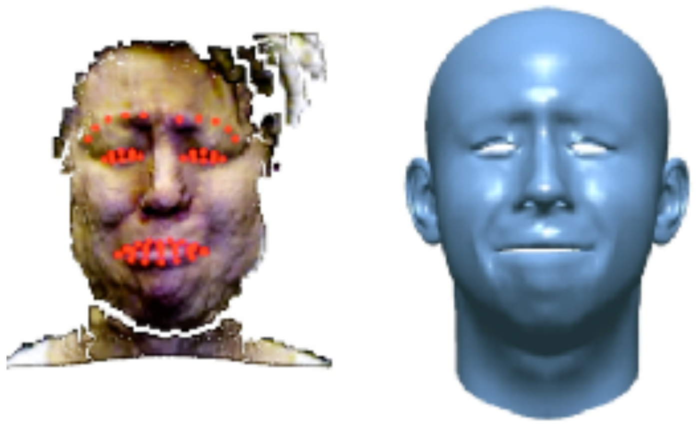
Faces 2014: Discussion

Bouaziz et al. 2013



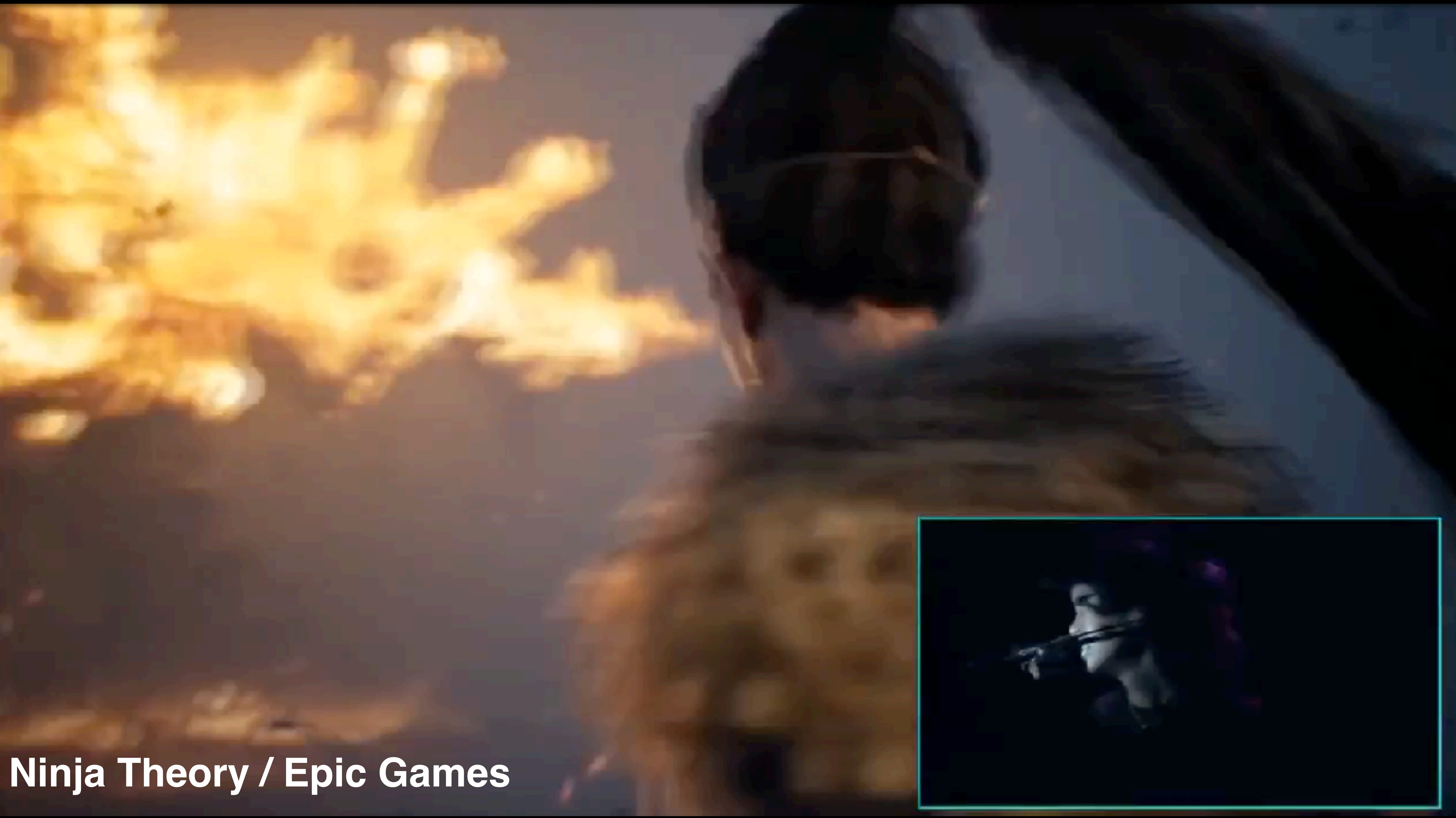
Cao et al. 2014

Li et al. 2013

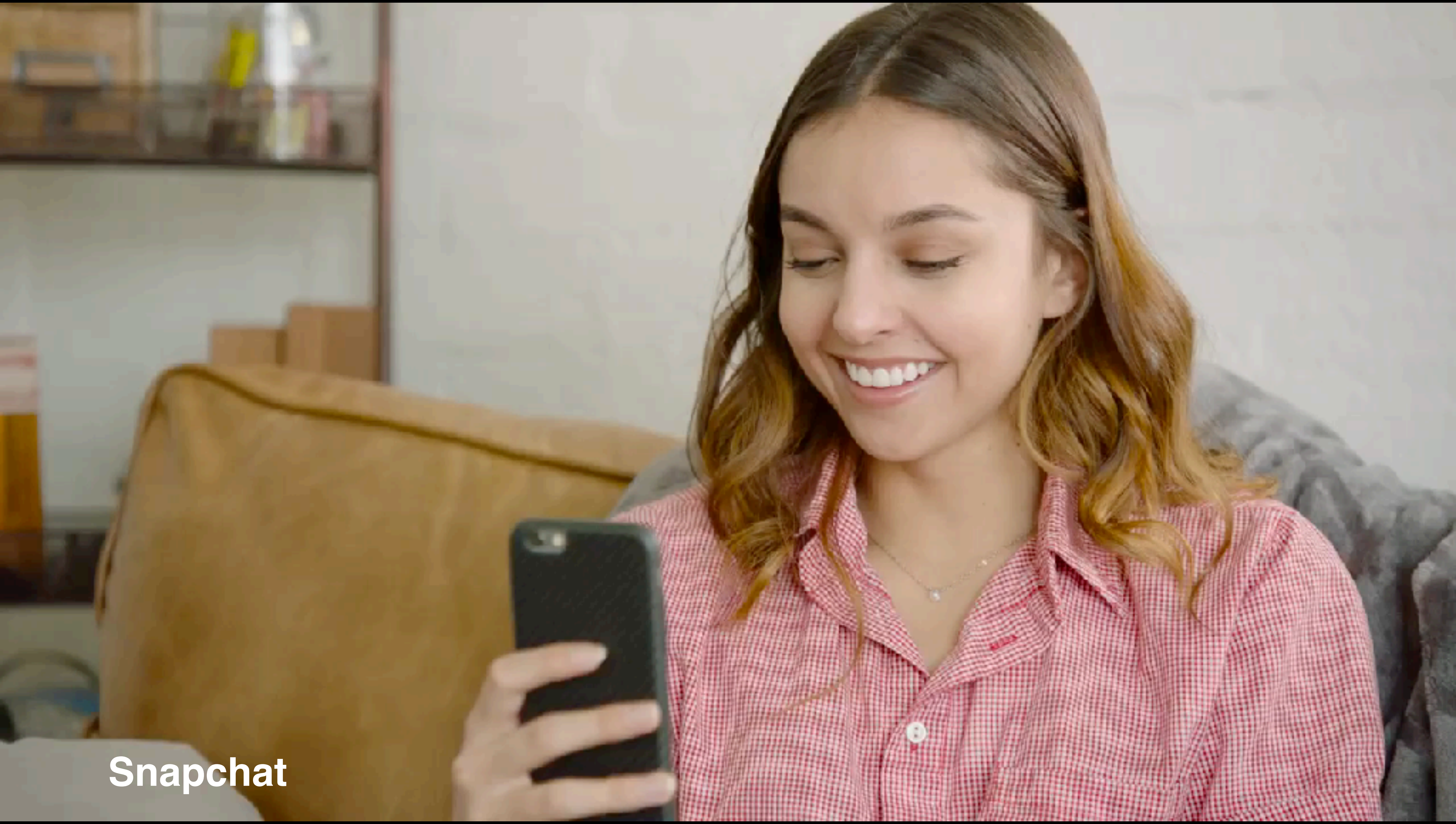


Bouaziz et al. 2013	Cao et al. 2014	Li et al. 2013
input 3D/2D	input 2D	input 3D/2D
no calibration	neutral face	neutral face
blendshape	blendshape	per-vertex deformation

Into the Mainstream



Ninja Theory / Epic Games


Snapchat

Facebook / MSQRD

FaceX Robustness

input video

face segmentation

FaceX Instant User Switching

input video

face segmentation

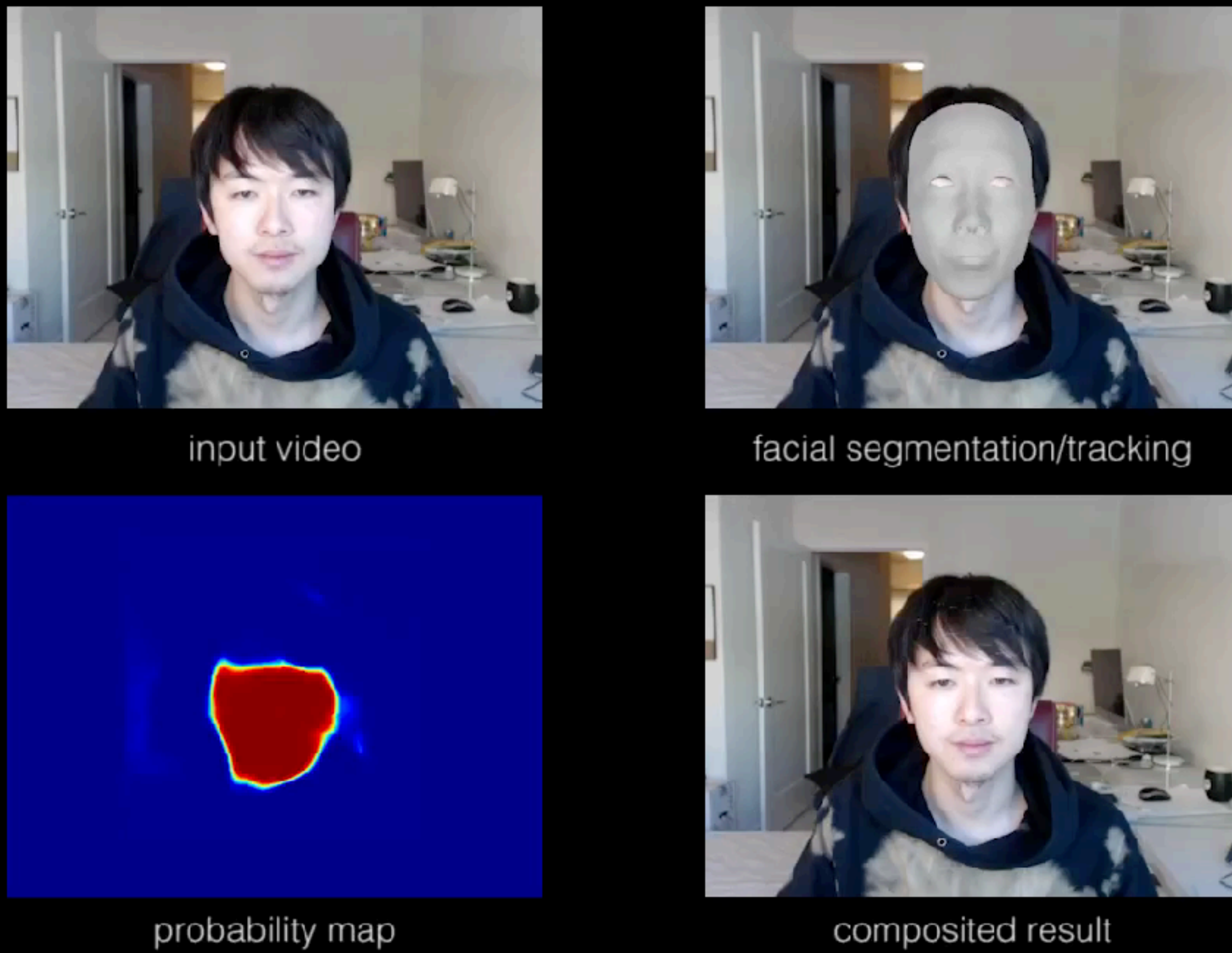
FaceX Kids

input video

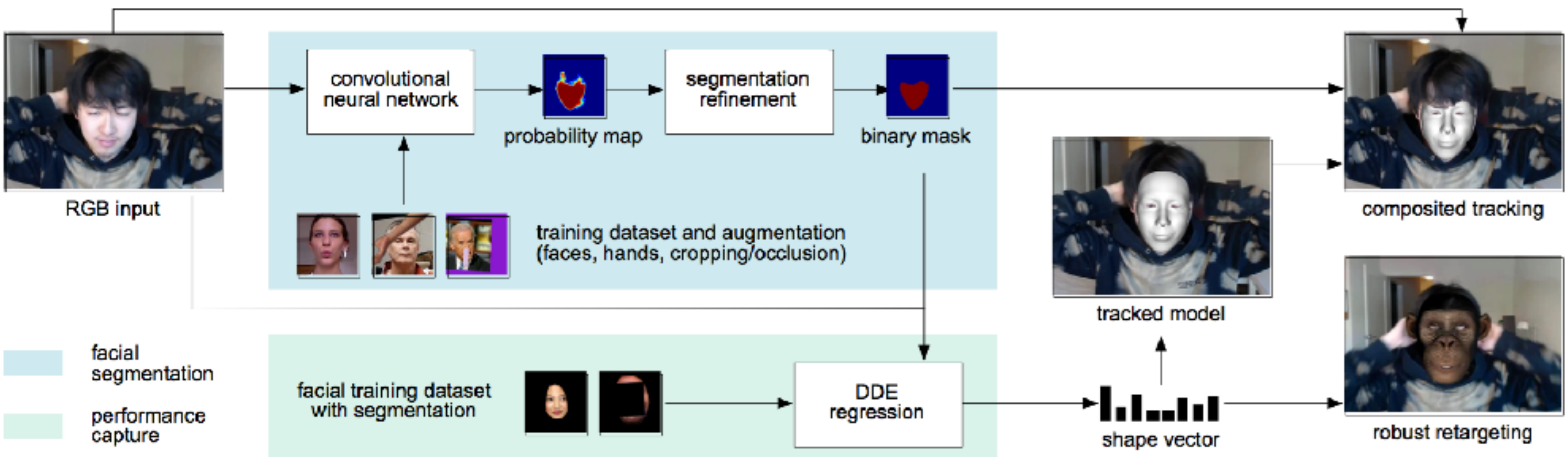
face segmentation

State-of-the-Art in Real-Time Facial Tracking

Preliminary Findings: Segmentation

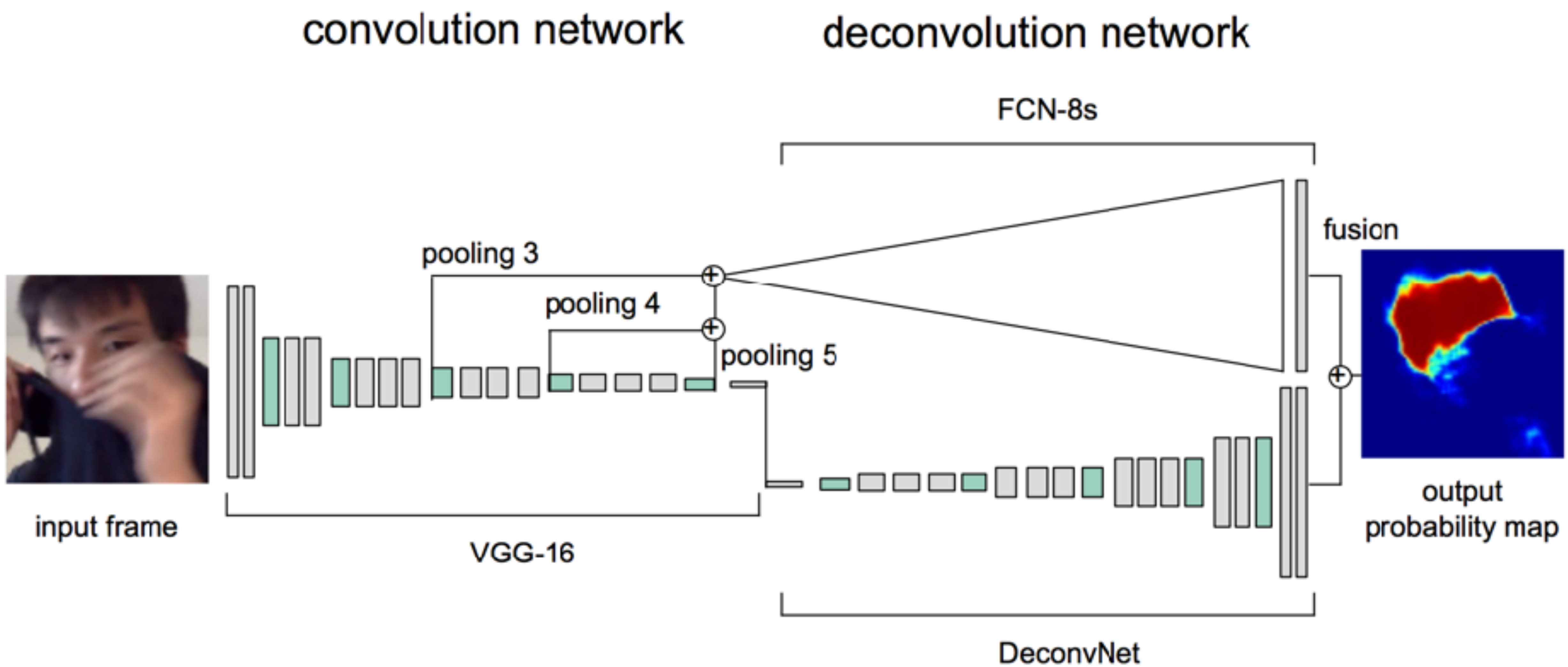


Pipeline

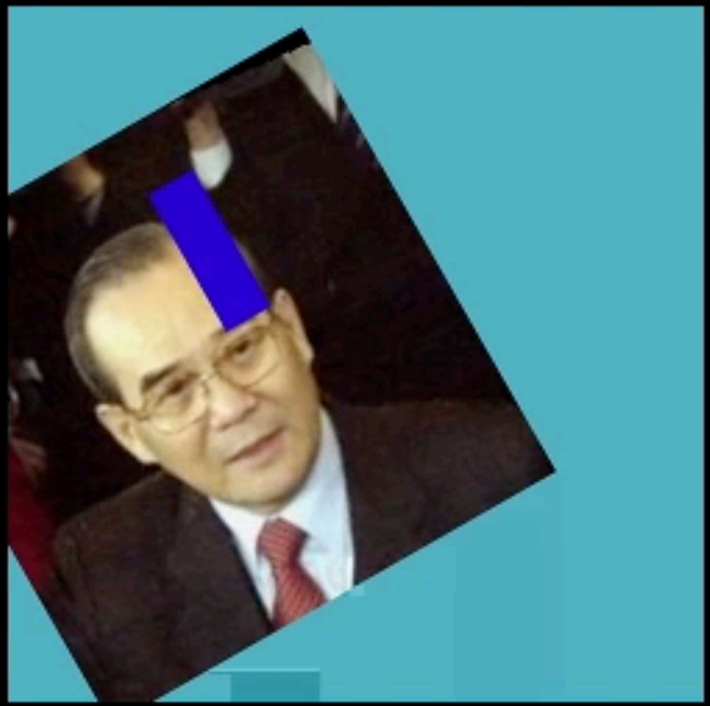


RGB input
convolutional neural network
probability map
segmentation refinement
binary mask
training dataset and augmentation (faces, hands, cropping/occlusion)
composited tracking
tracked model
robust retargeting
facial segmentation
performance capture
facial training dataset with segmentation
DDE regression
shape vector

Two-Stream Deconvolution Network



face data



occlusion / cropping

hand over face compositing

negative hand data

Comparison

input video

Cao et al. 2014

our method

Open Problems

USC/ICT Activision

Open Problems

Melbourne Acting School 2010

Virtual Reality

Once upon a dream

Virtual Reality **Reloaded**

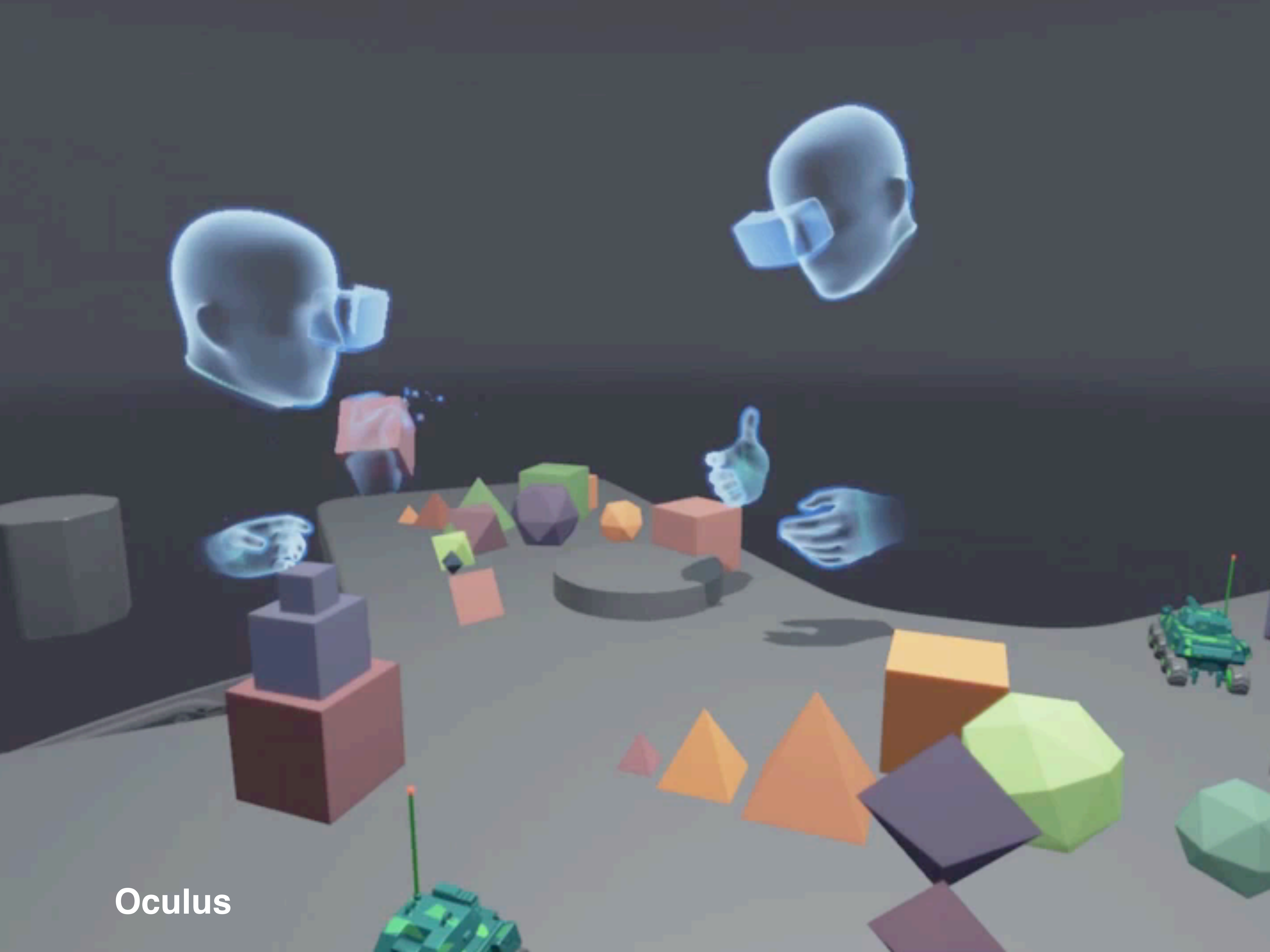
Oculus VR 2012 / Crytek 2014

Consuming VR


Oculus

NextGen Communication Platform

Online Virtual Worlds



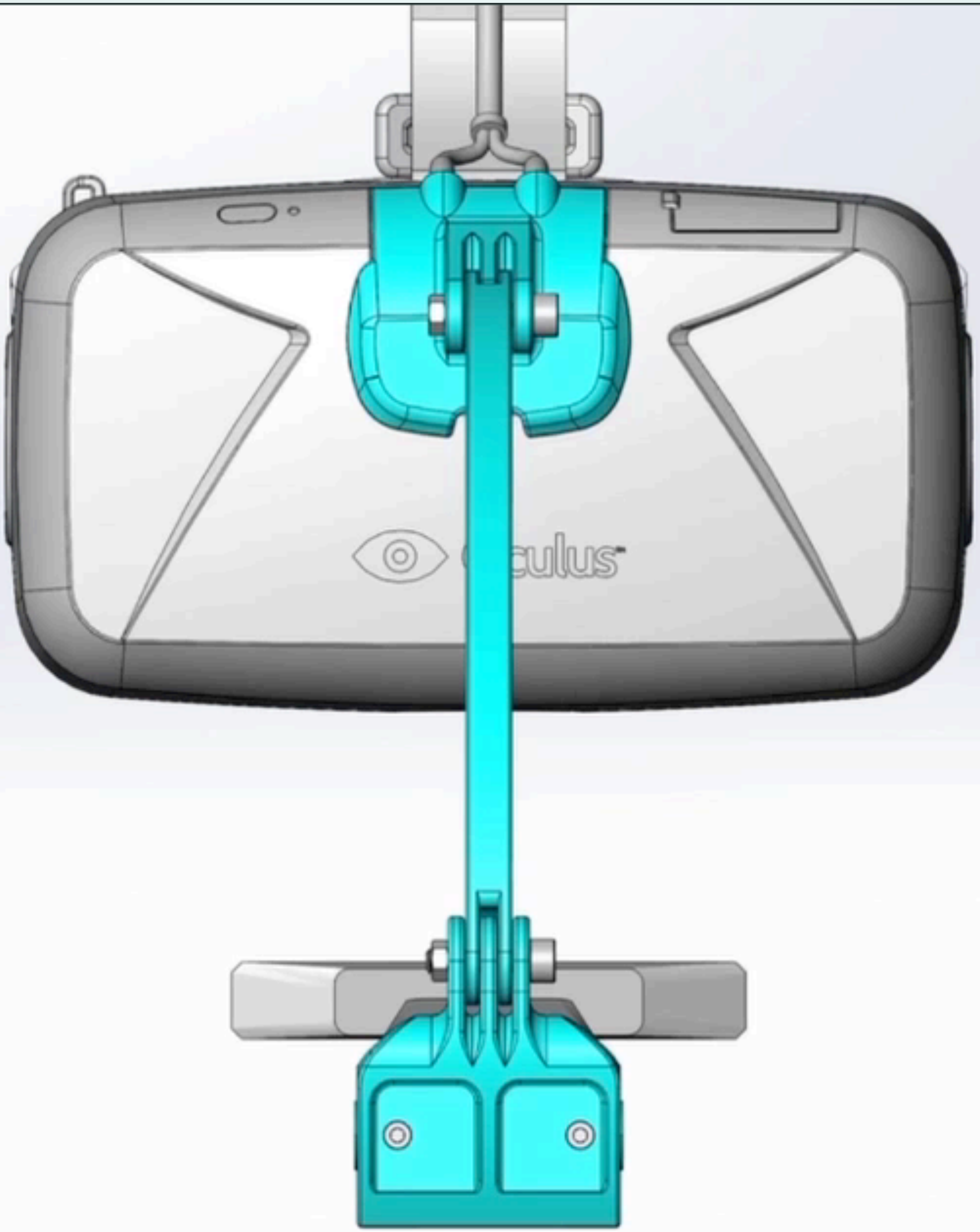
Oculus


Lucy
Michael

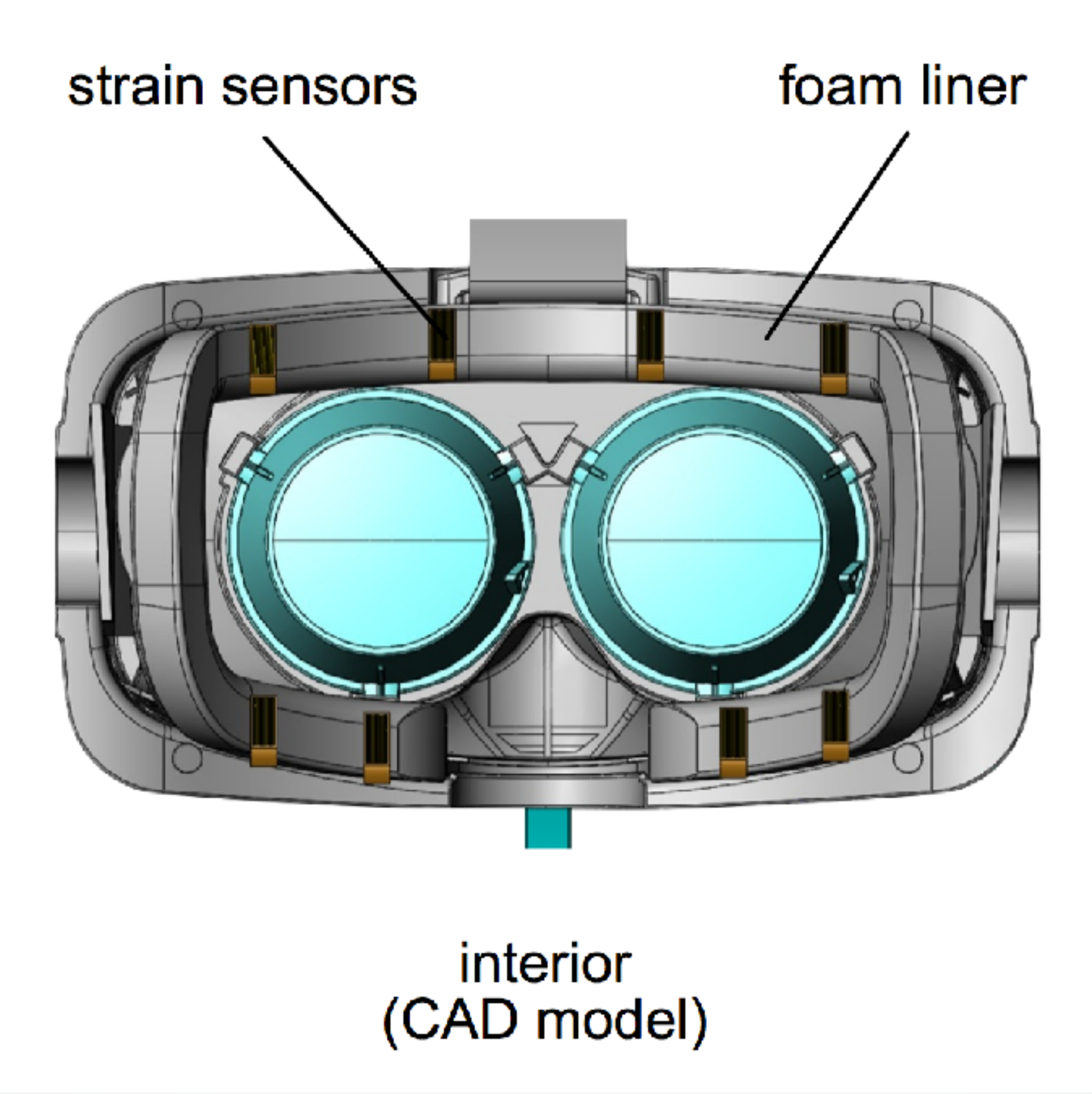
Occlusions

Preliminary Findings: Segmentation

Facial Performance Sensing HMD



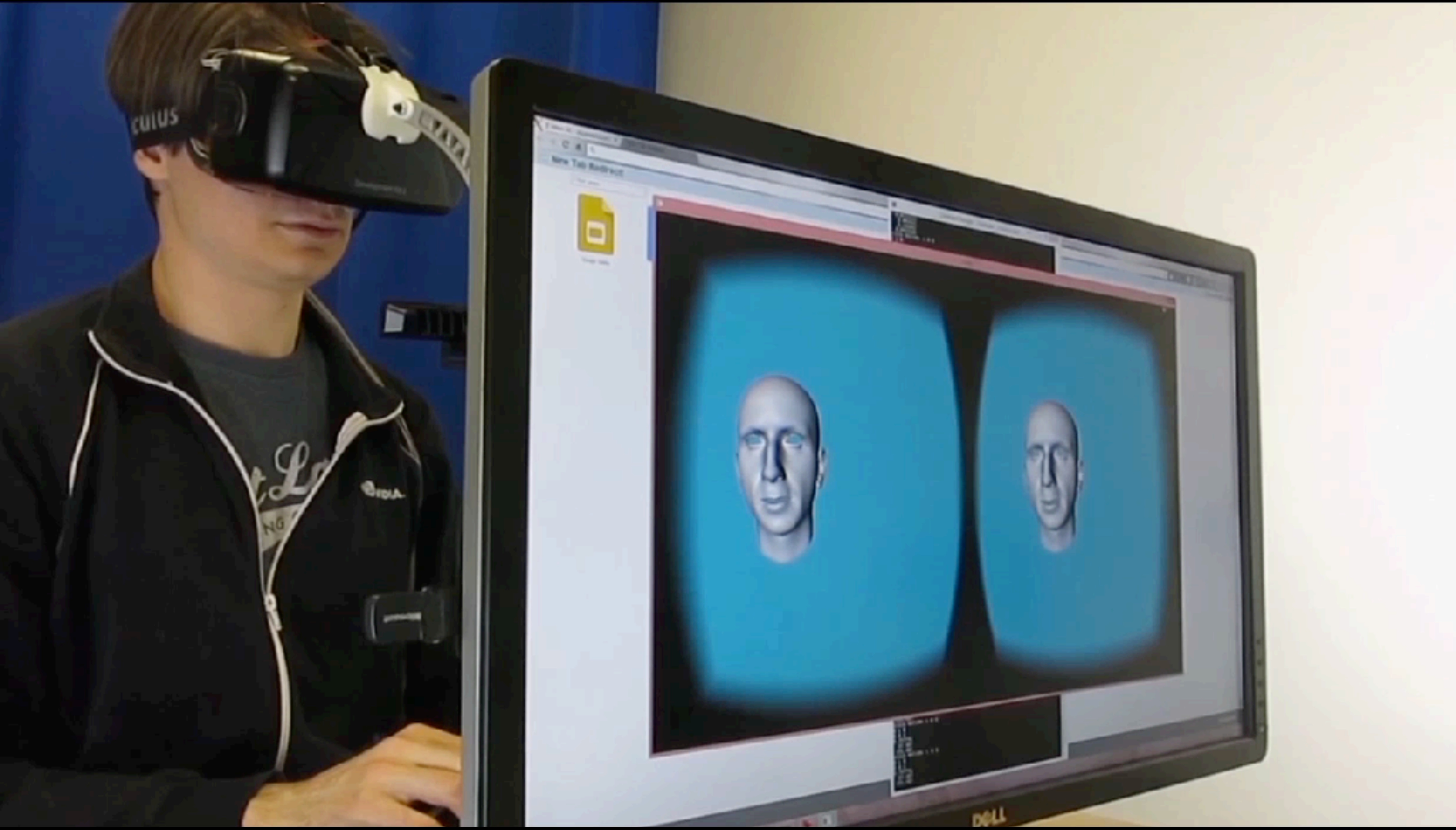
Facial Performance Sensing HMD



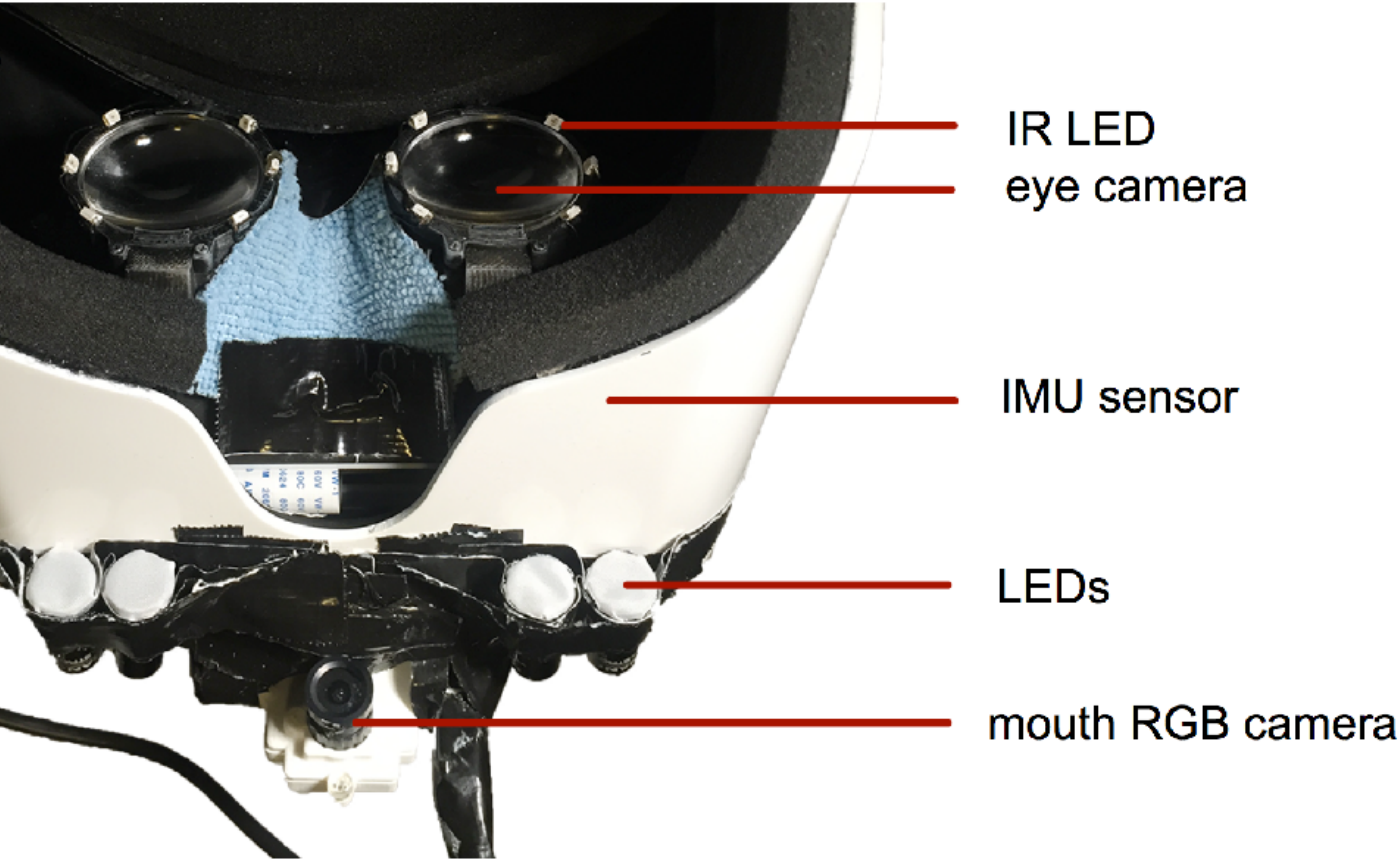
Facial Performance Sensing HMD

Ultra Thin Flexible Electronic Materials

Live Demo

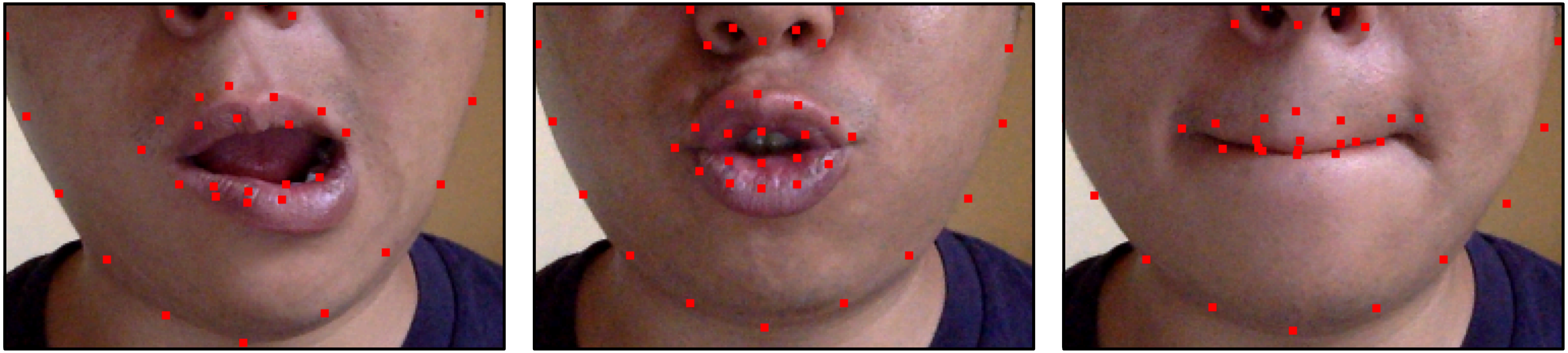


HMD Prototype Design

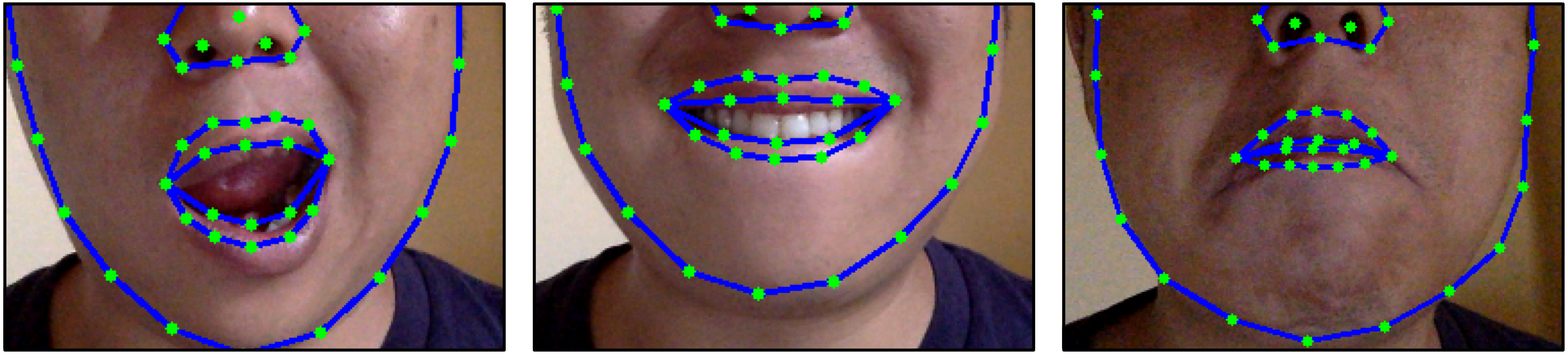


IR LED
eye camera
IMU sensor
LEDs
mouth RGB camera

Feature-Based Tracking



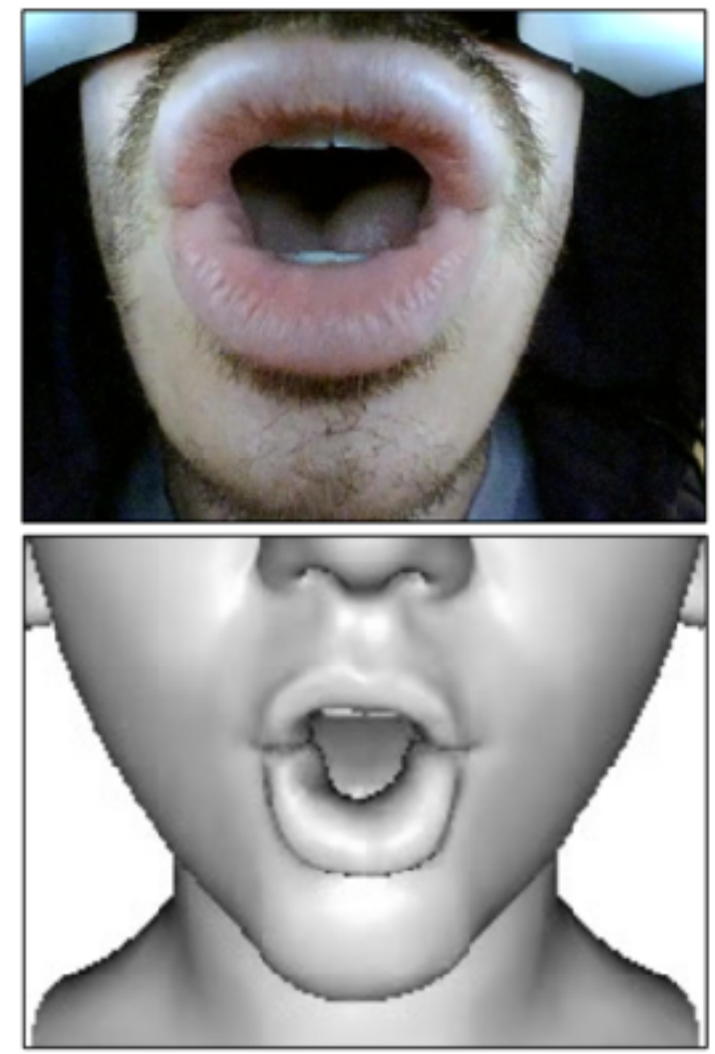
Kazemi and Sullivan, CVPR 2014



Cao et al., SIGGRAPH 2014

High Dimensionality & Non-Linearity

occlusions, lighting, expressions, identity



sticky lips, biting, visemes, …

Deep Learning Model for Facial Expressions

$$f^t = \mathbf{b}_0 + \sum_i^N \mathbf{w}_i^t (\mathbf{b}_i - \mathbf{b}_0)$$

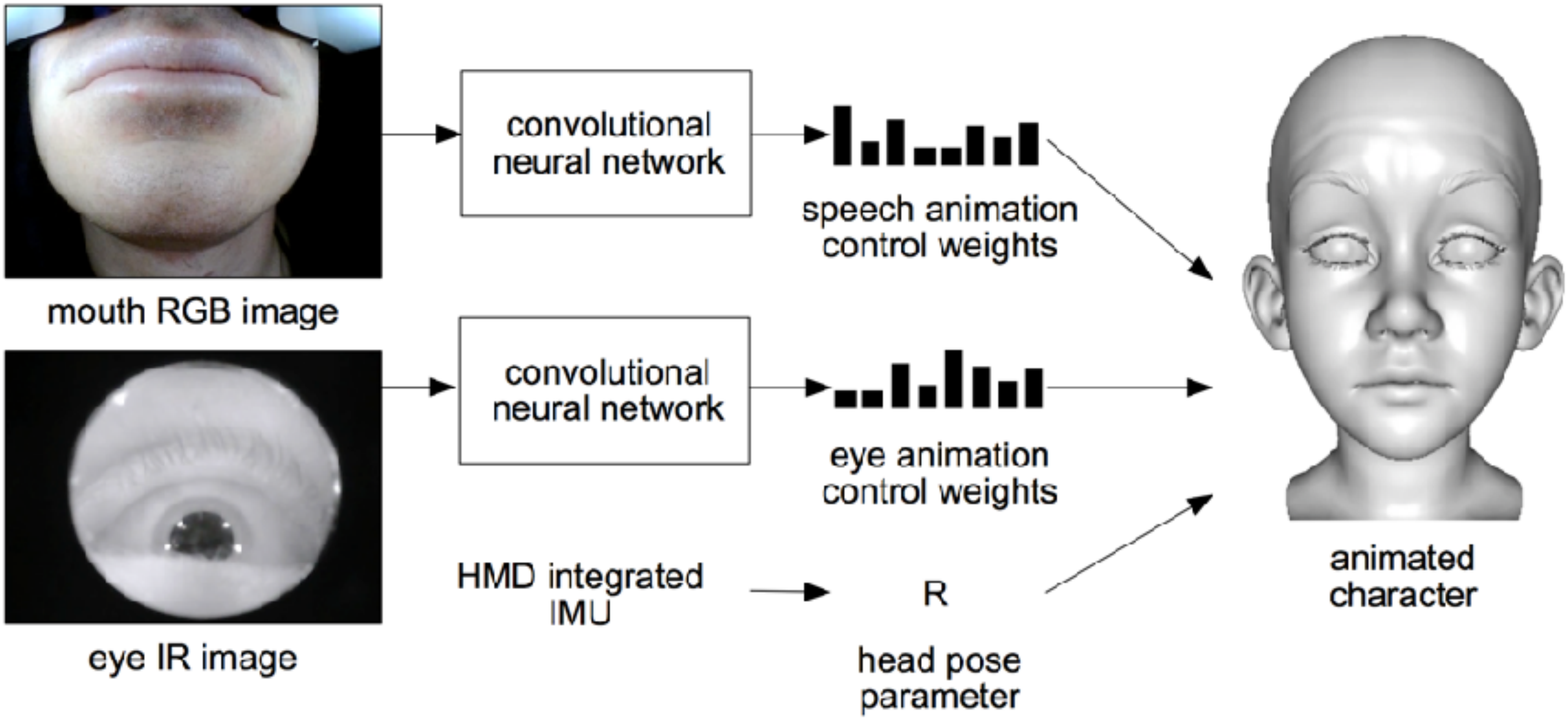
non-linear

$$L(\psi) = \sum_t \|\psi(I^t) - \mathbf{w}^t\|_2^2$$

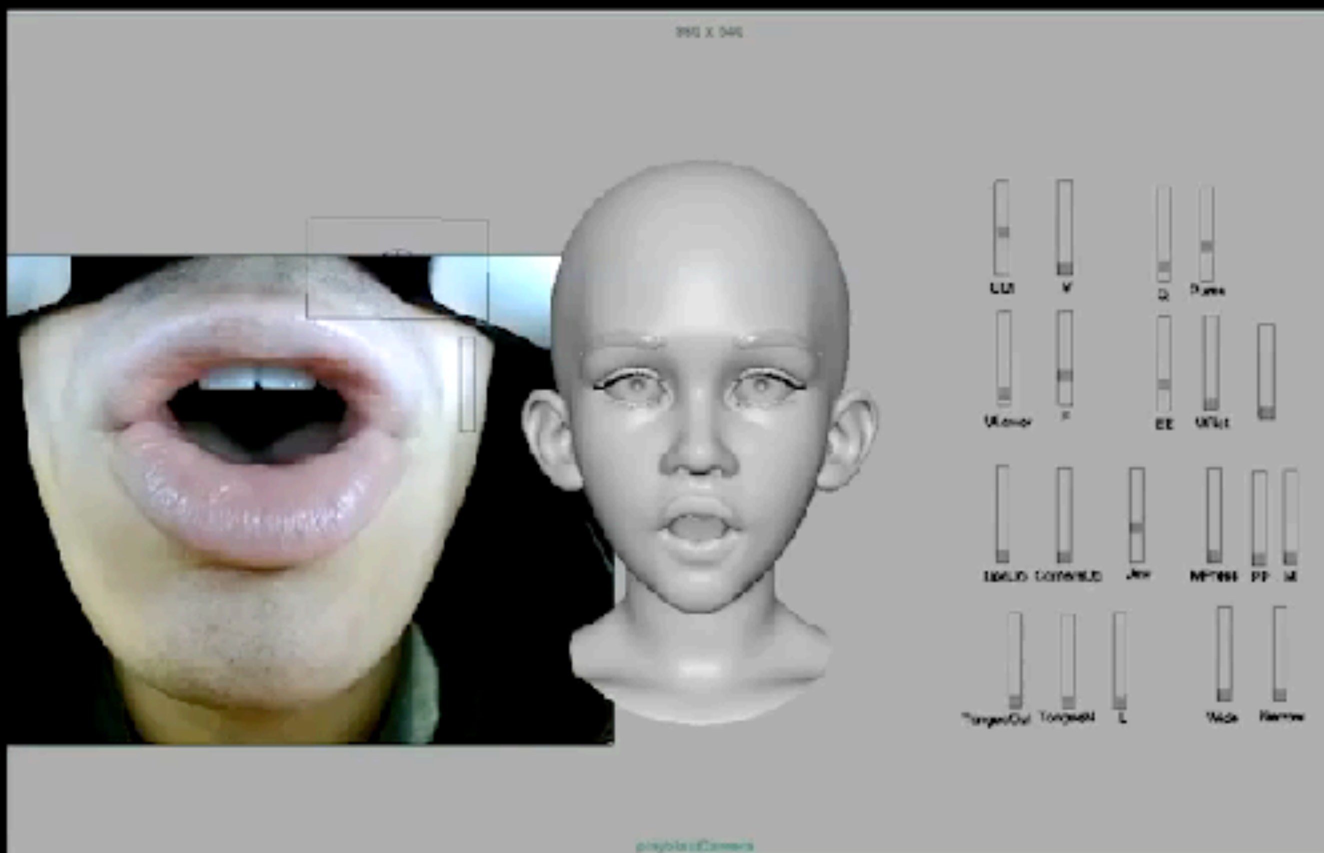
high dimensional

low dimensional

Online Operation



Label Transfer via Audio Alignment

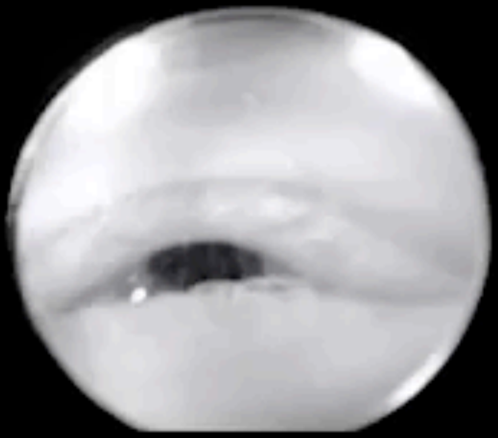


reference data

reference animation

dynamic time warped training data

Eye Animation Results



input video

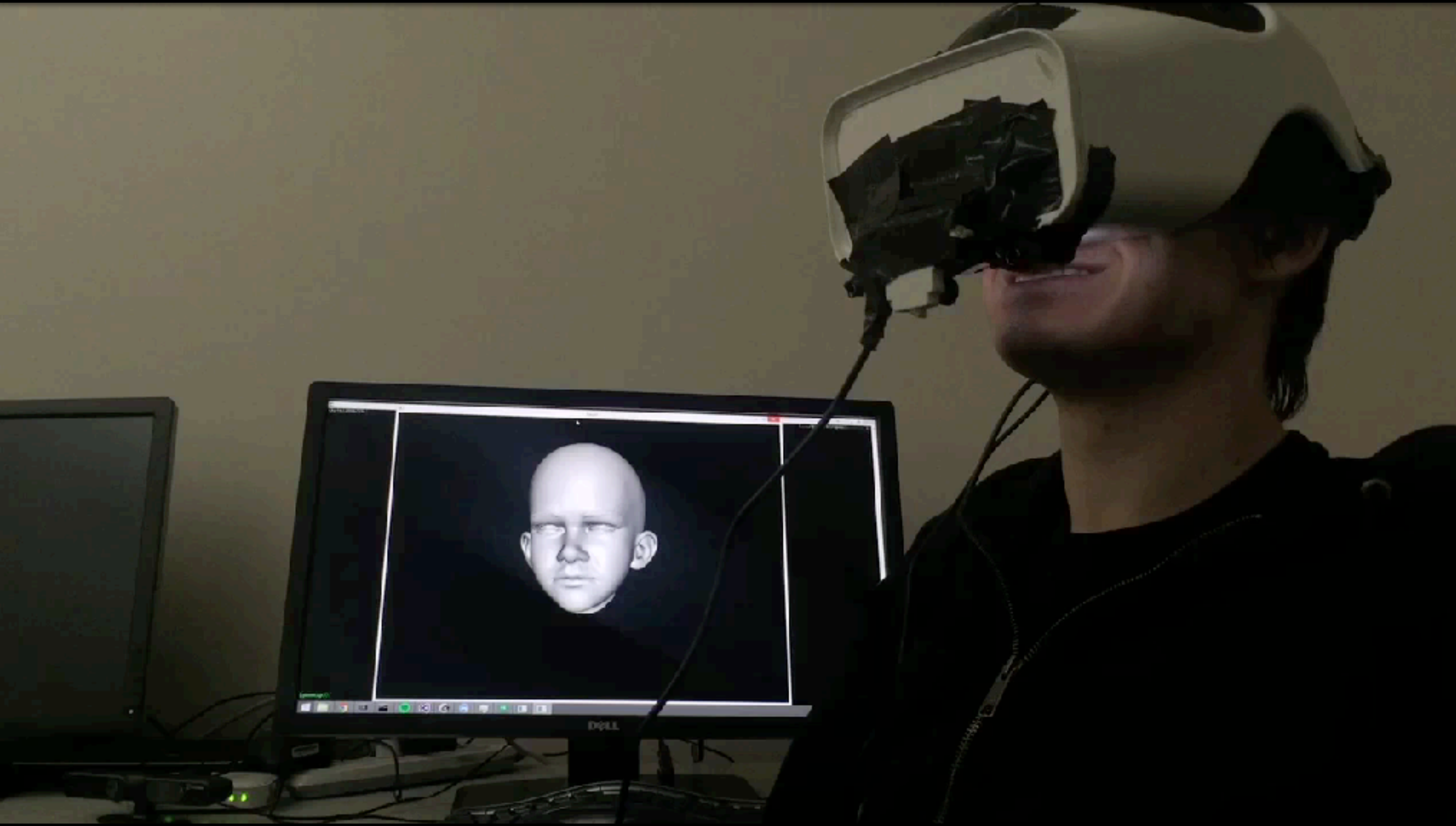
output animation

Retargeting

input performance

mouth camera

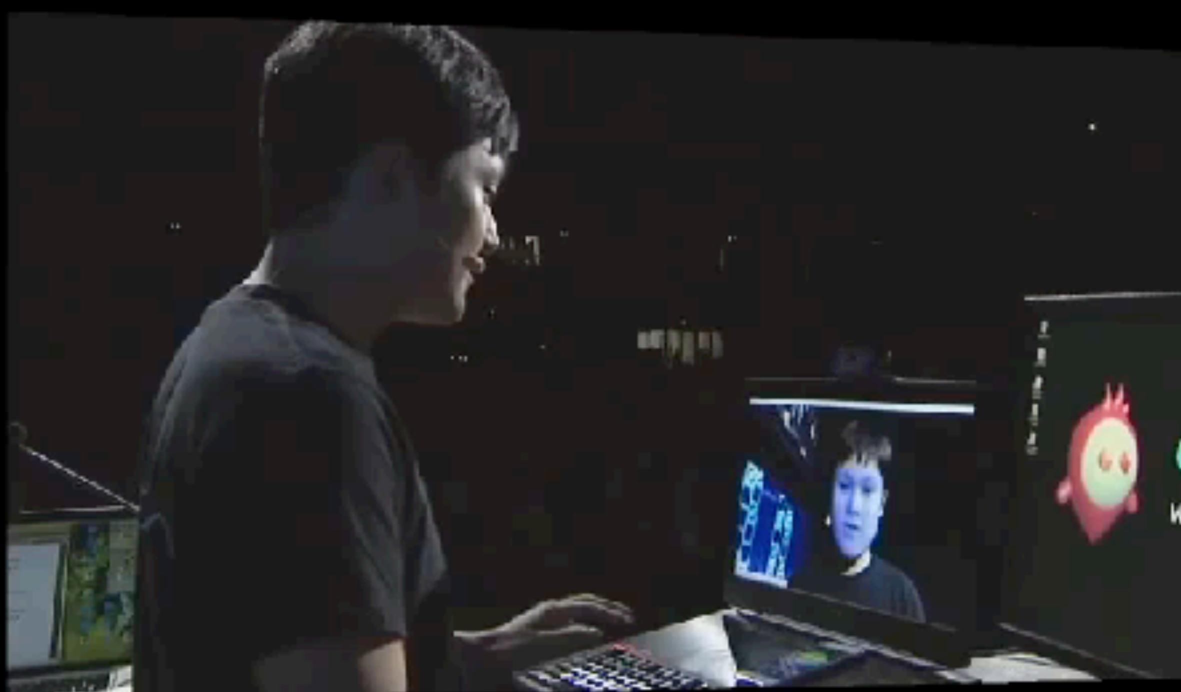
real-time
facial animation


DELL

Full Facial Performance Capture

Character 1
Validation shot 1

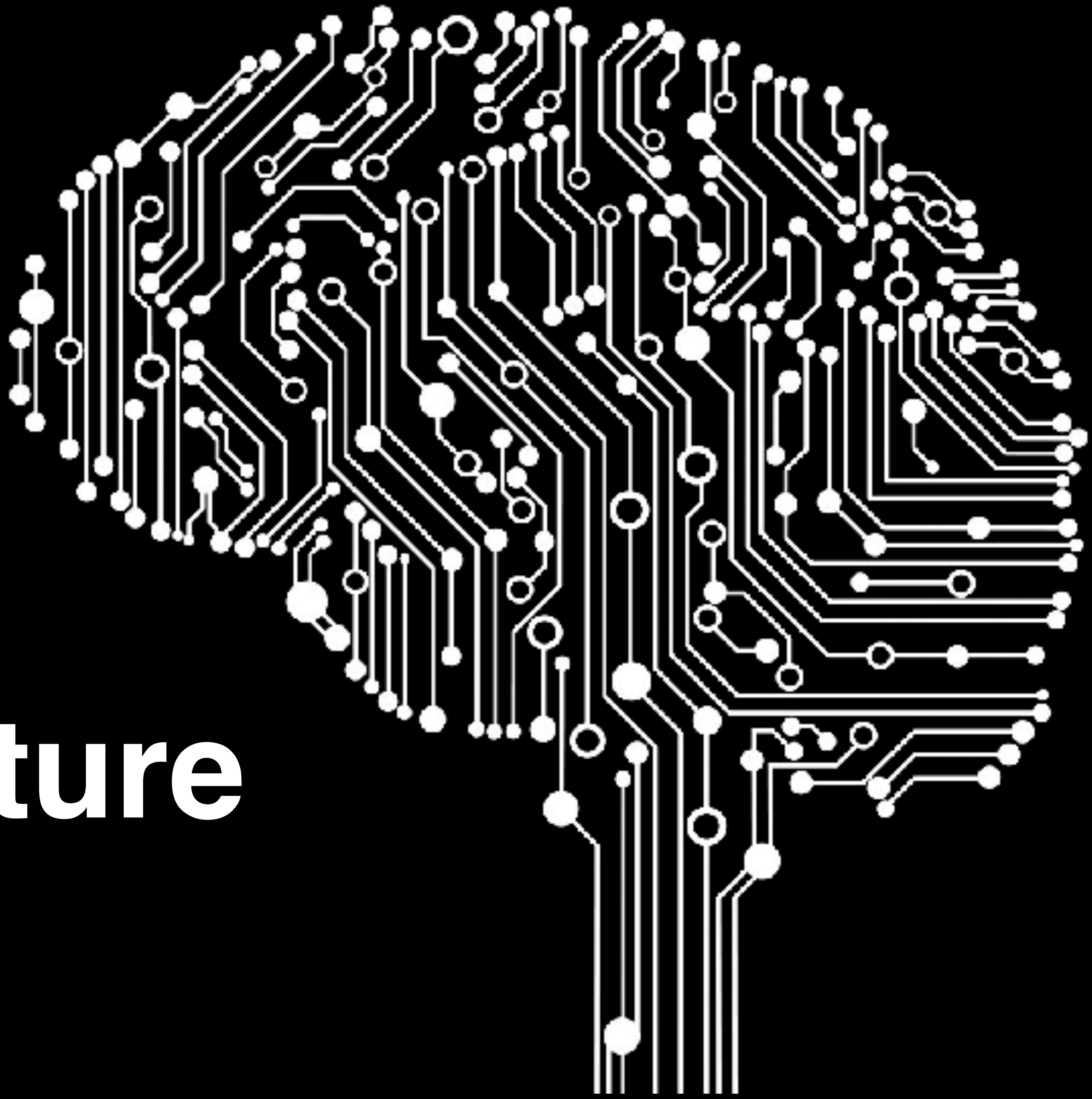
AR-Enabled Face Tracking



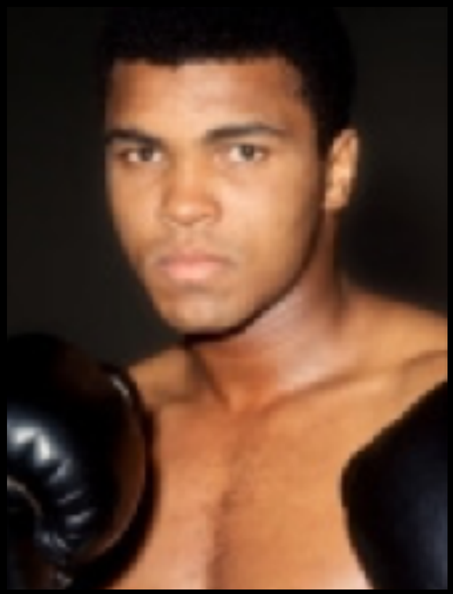
SIGGRAPH 2017

Instant Avatars

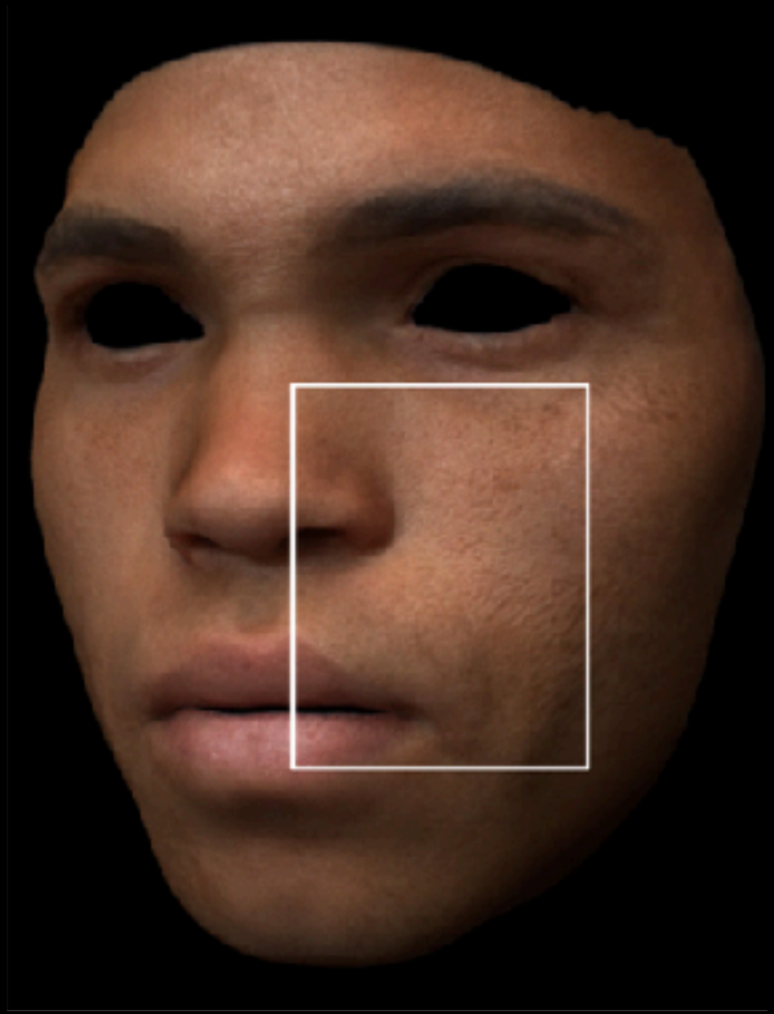
The Future



Photorealistic Transfer



input image



3D model with photorealistic texture

Saito et al. (2017)

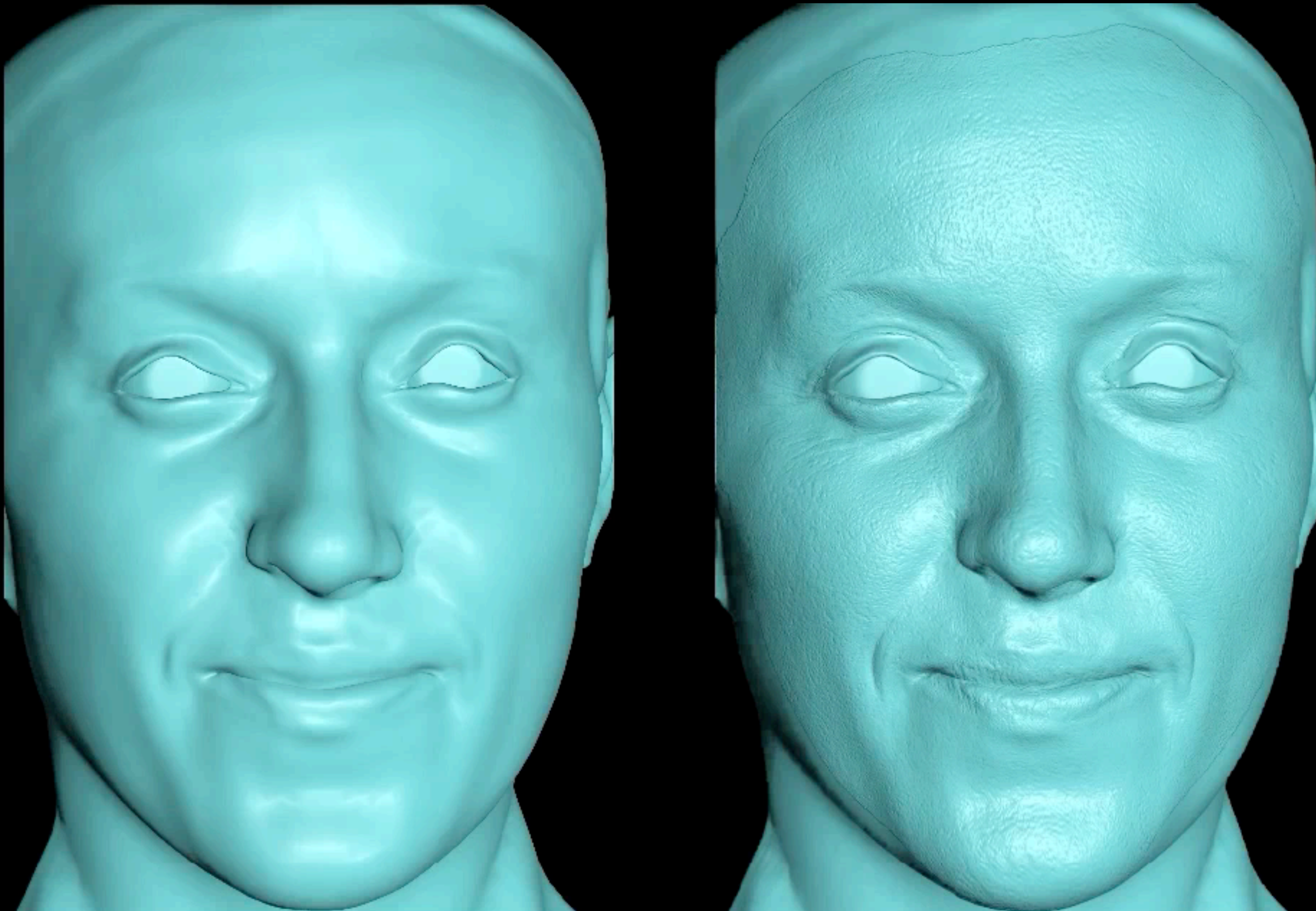
Photorealistic Transfer

Saito et al. (2017)

input 2D image

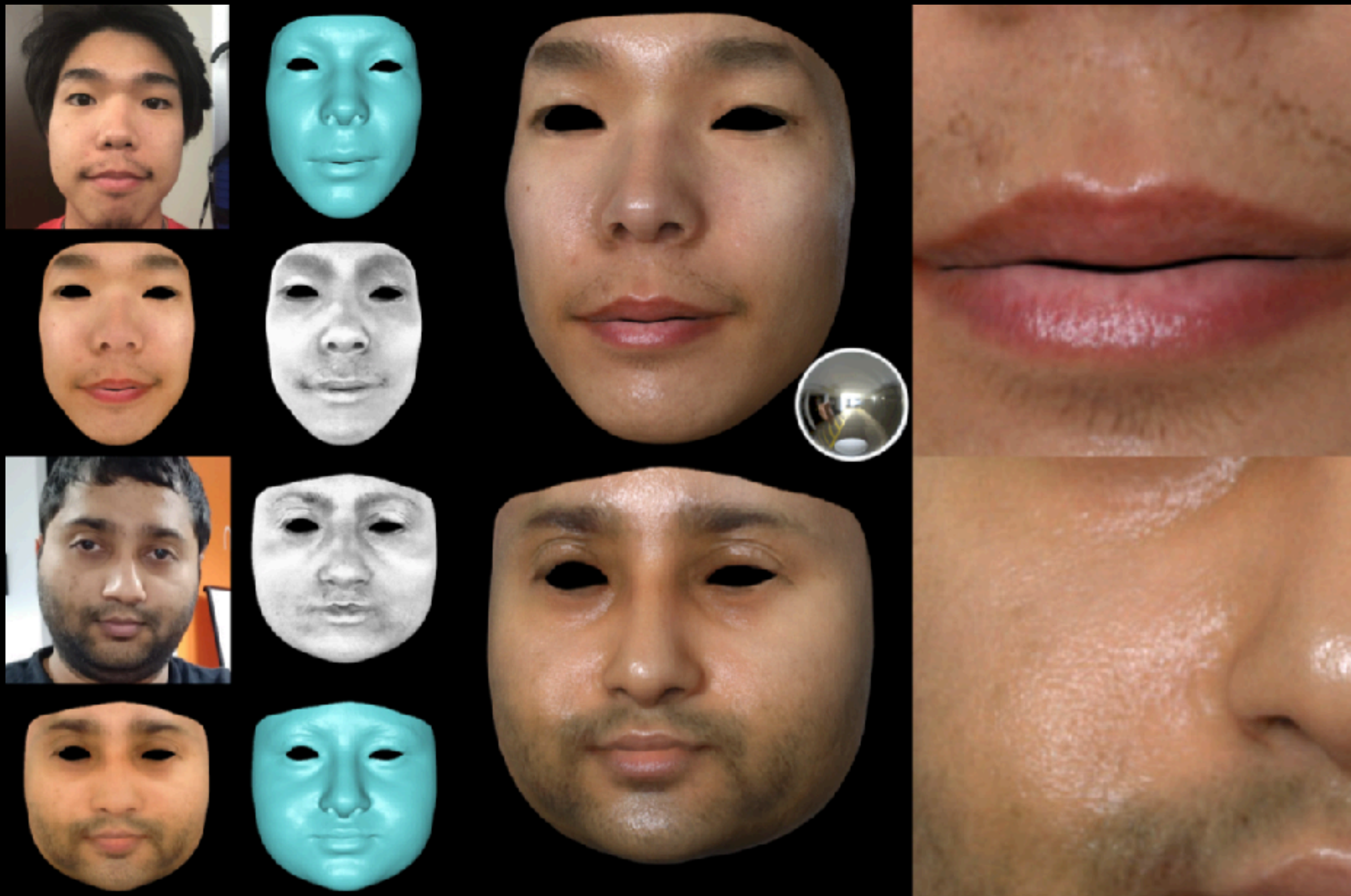
output textured 3D face (AFW)

Geometry Synthesis



Huynh et al. (2018)

Full Geometry and Reflectance Inference



Yamaguchi et al. (2018)

Facial Expression Synthesis

Nagano et al. (2018)

Photoreal Avatar Creation

Nagano et al. (2018)

Disney

Fake News

http://cs621.hao-li.com

Thanks!