# Real-time Facial Animation
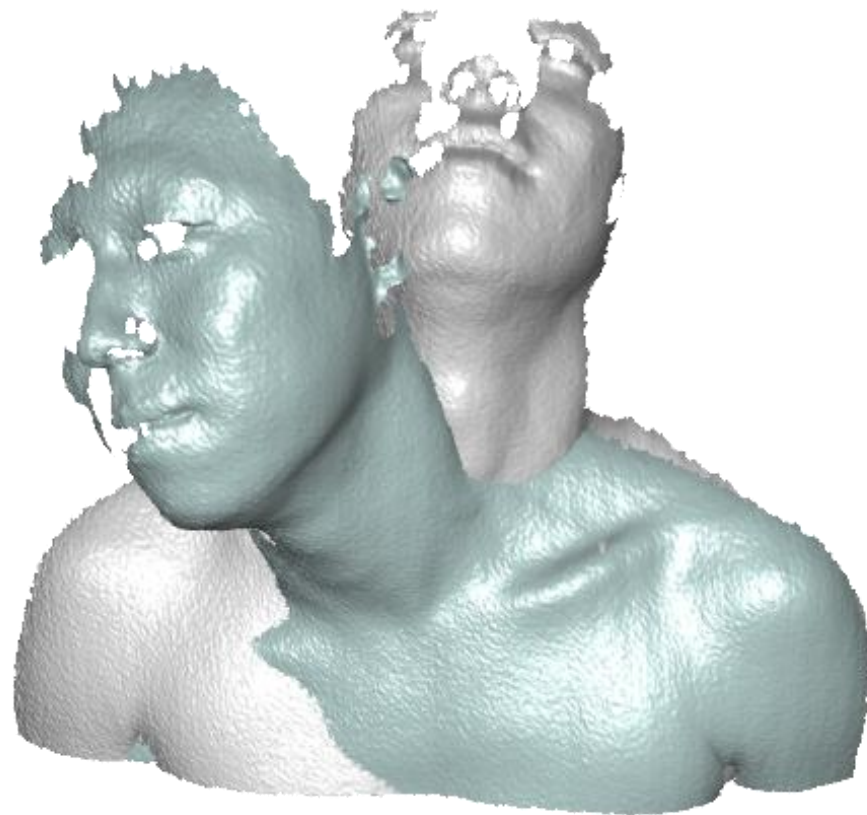
Hao Li & Mark Pauly

# Template Personalization
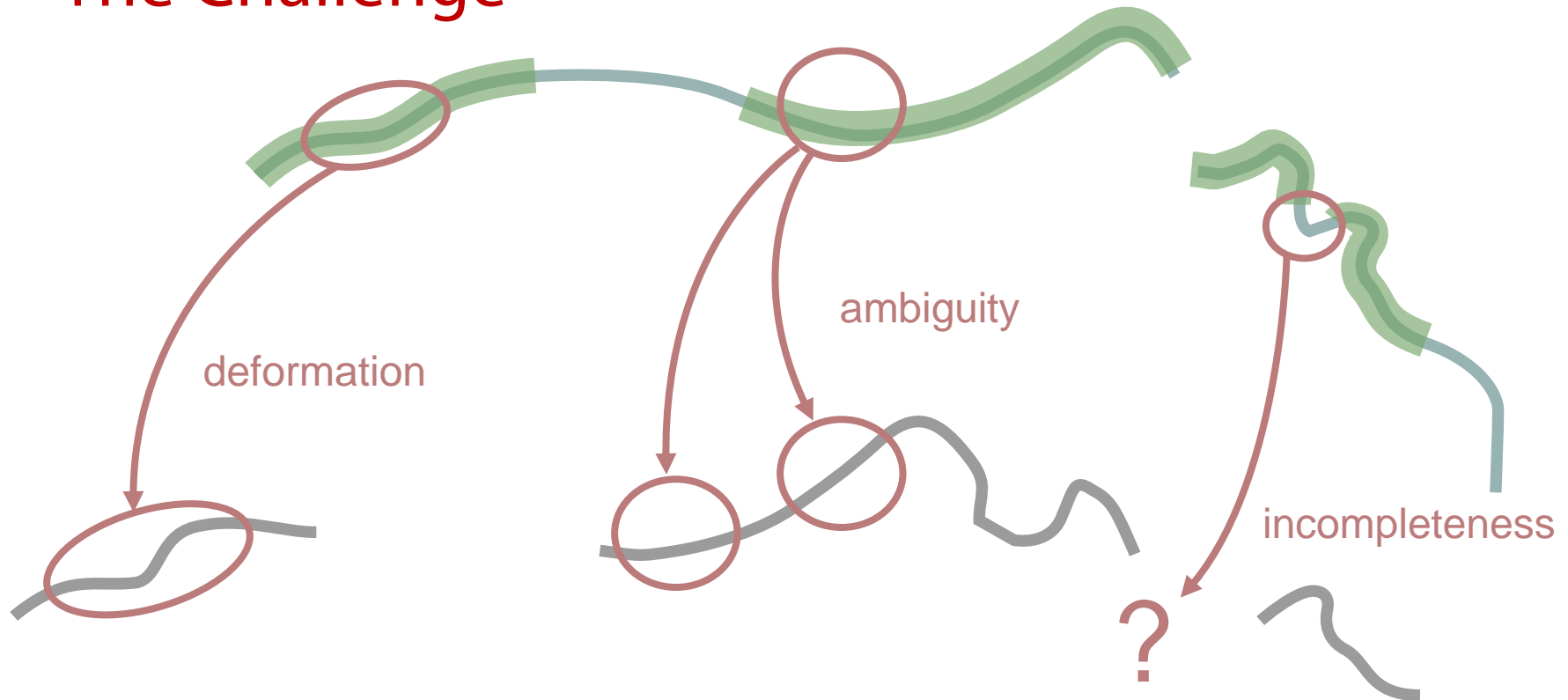
# Pair of 3D Scans



target

source
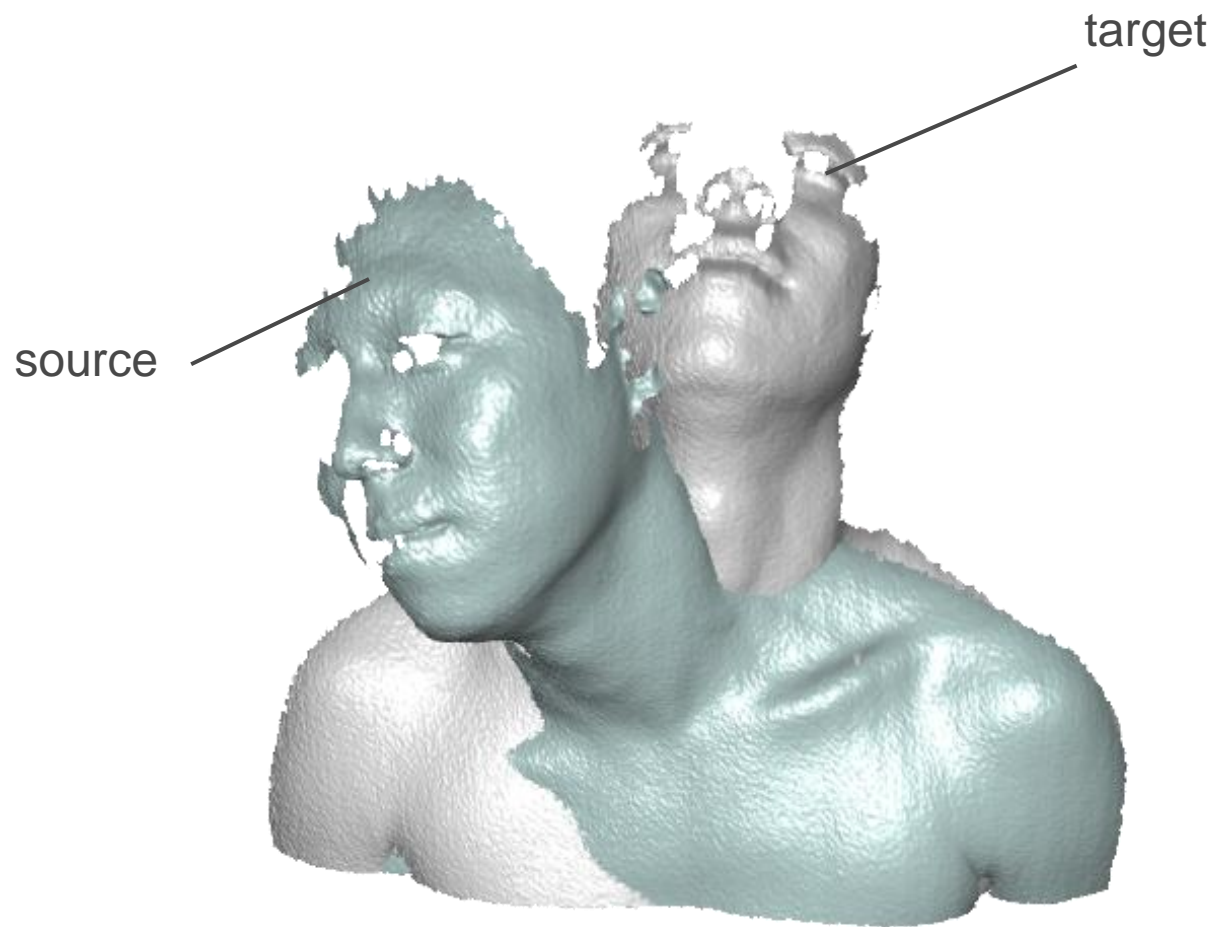
# Non-Rigid Registration

# The Recipe

source

registration

target



| detect overlap | ➔ | correspond | ➔ | deform |

# The Challenge



deformation

ambiguity

incompleteness

?

detect overlap → correspond → deform

# The Challenge

incomplete

correspondences

detect overlap ▷ correspond ▷ deform

# Observation



correspond

helps

helps

detect overlap

deform

# Global Optimization

correspond

detect overlap

deform
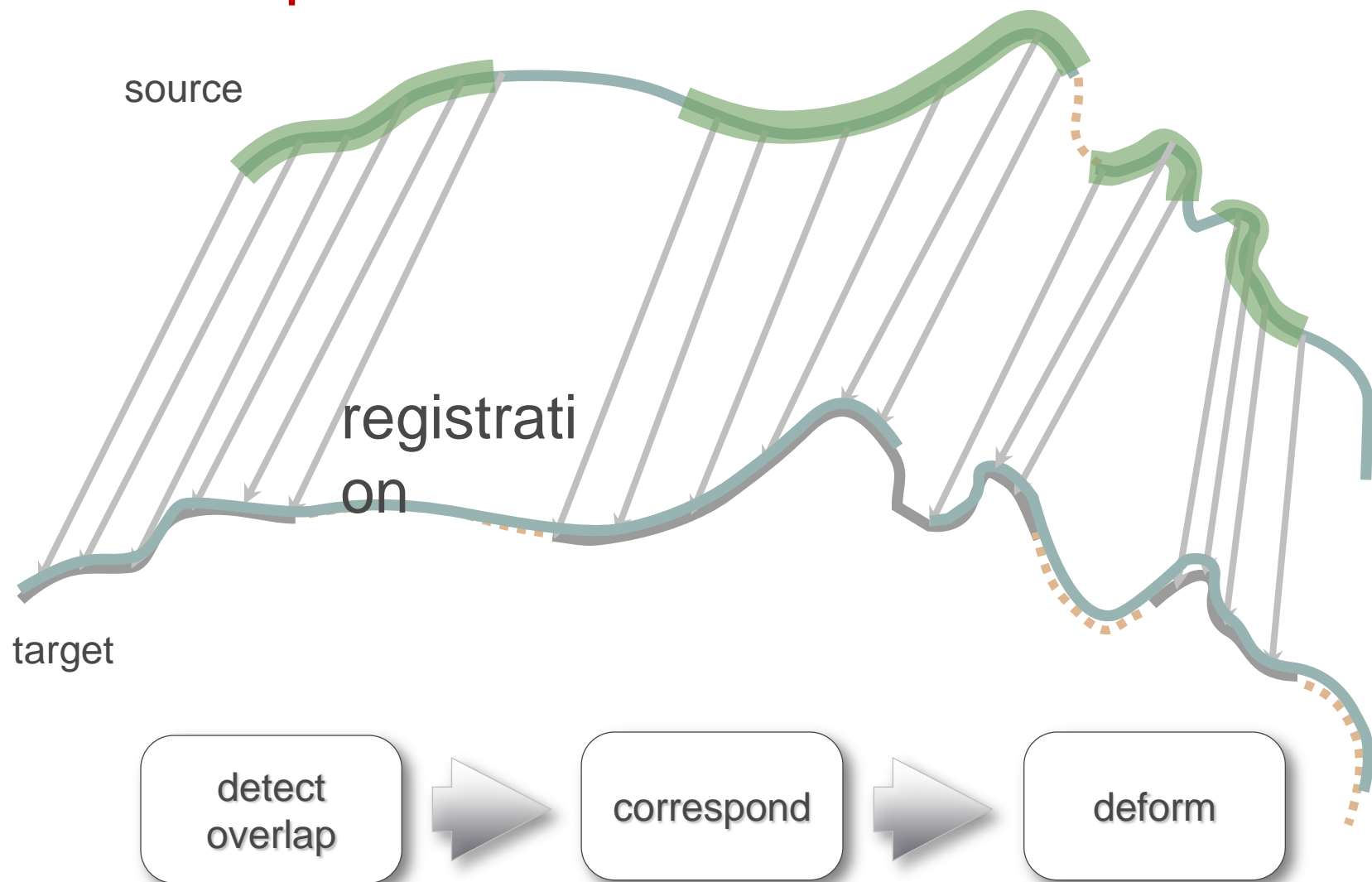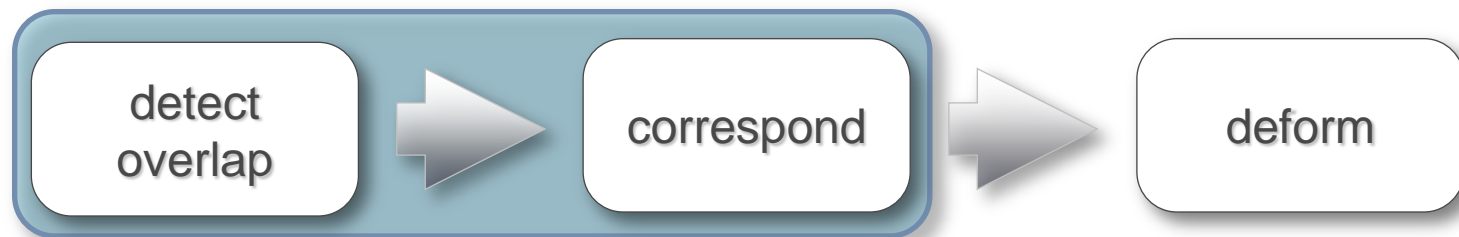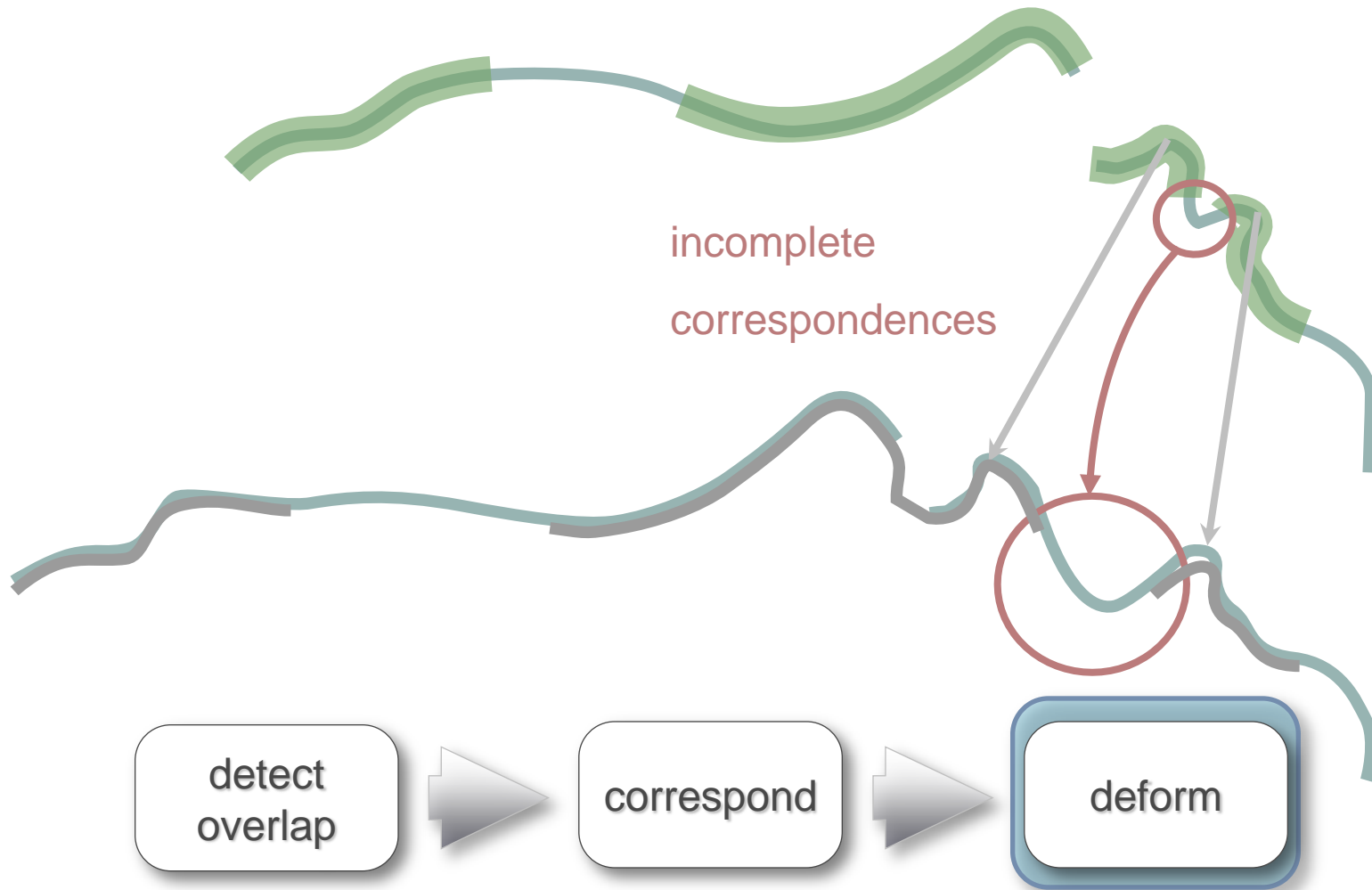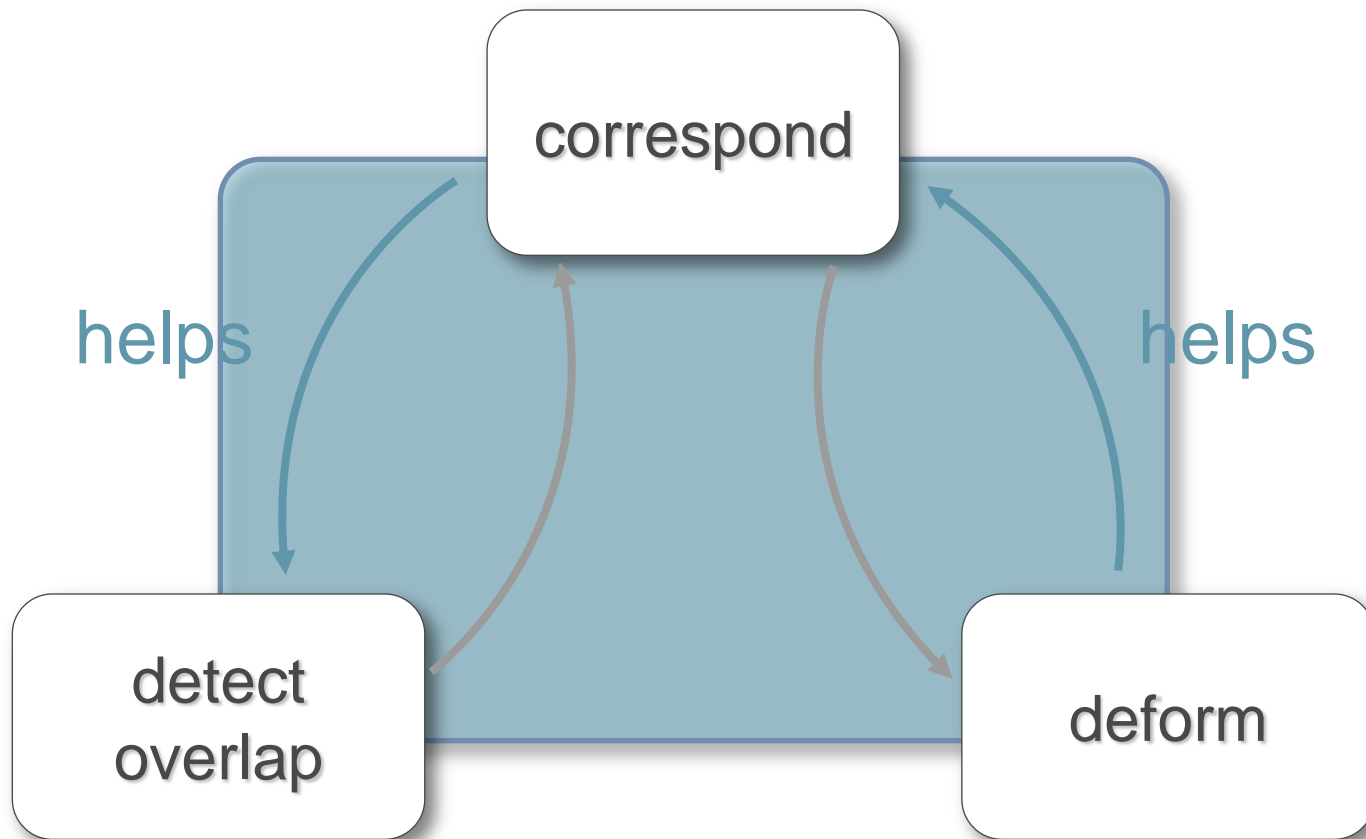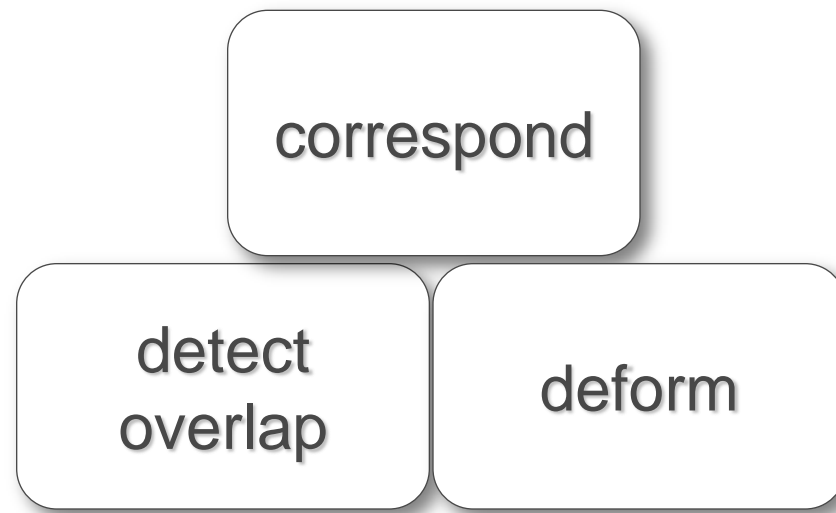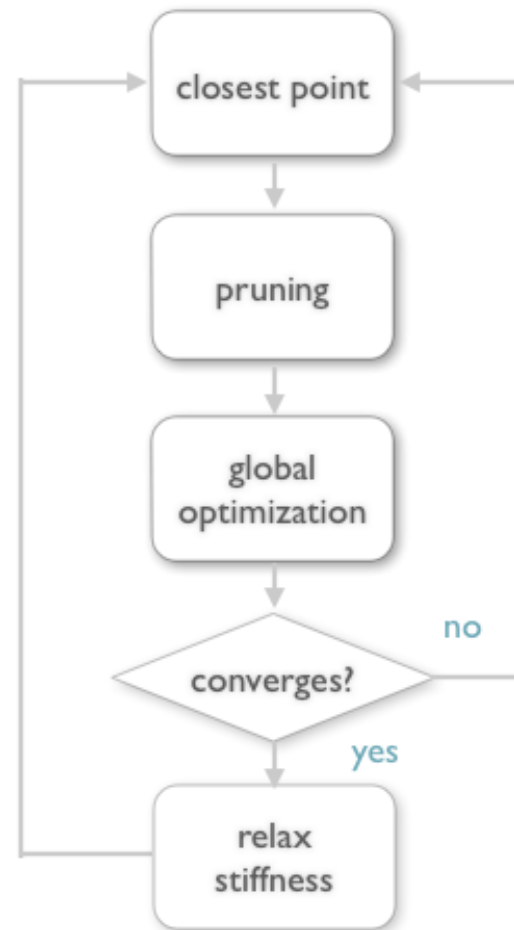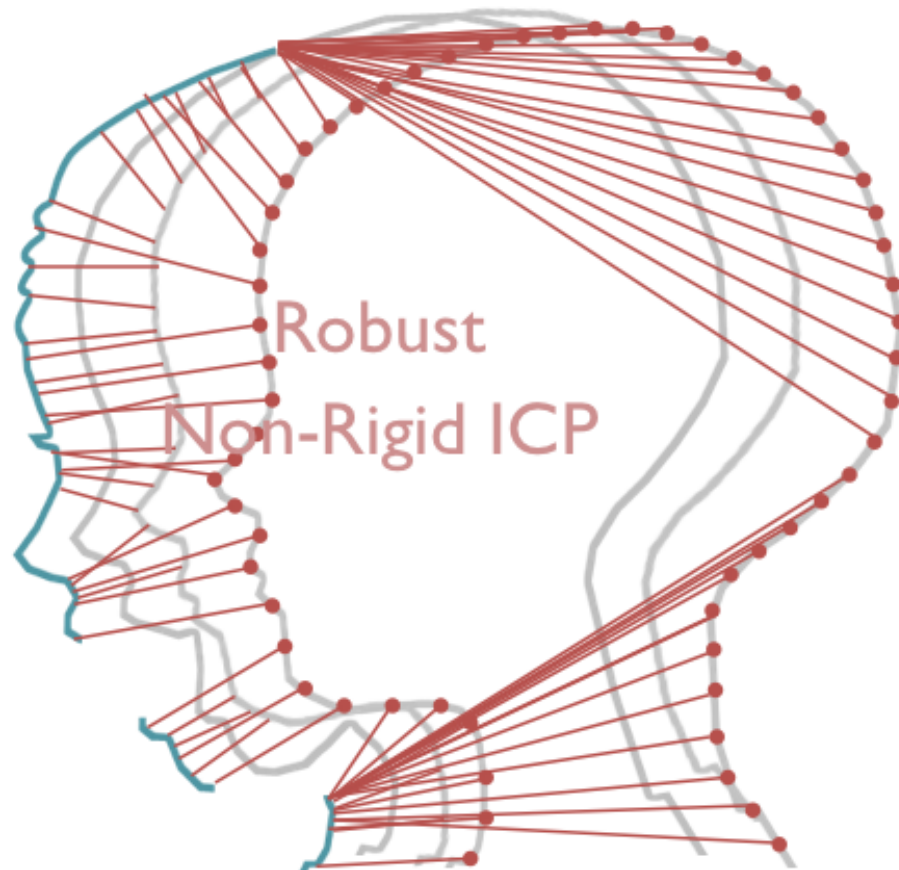
# Non-Rigid ICP

# Face Fitting

# PCA Subspace



average

$$= + w_0 + w_2 \cdots$$

PCA modes

Blanz & Vetter al. 99
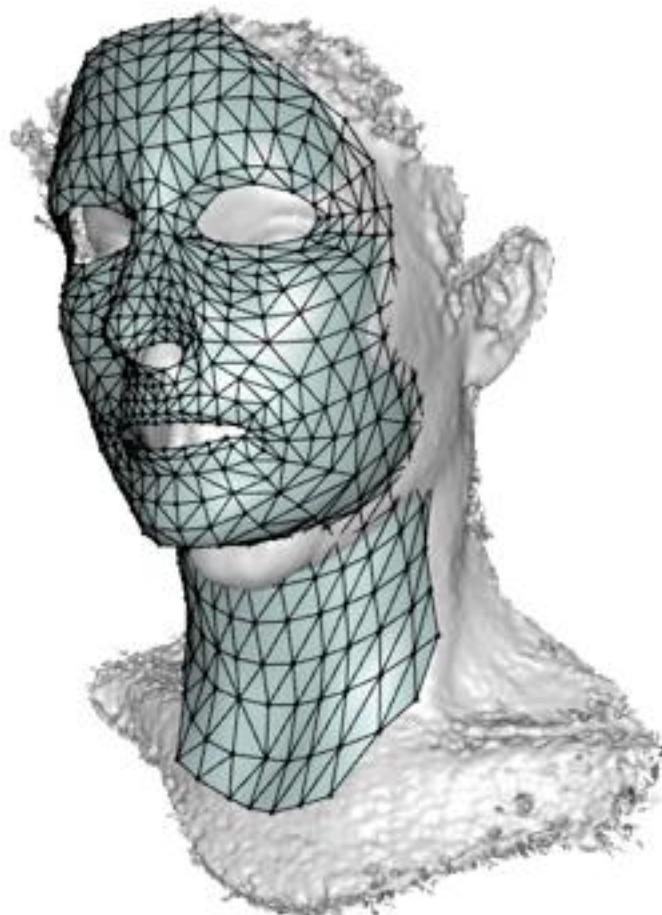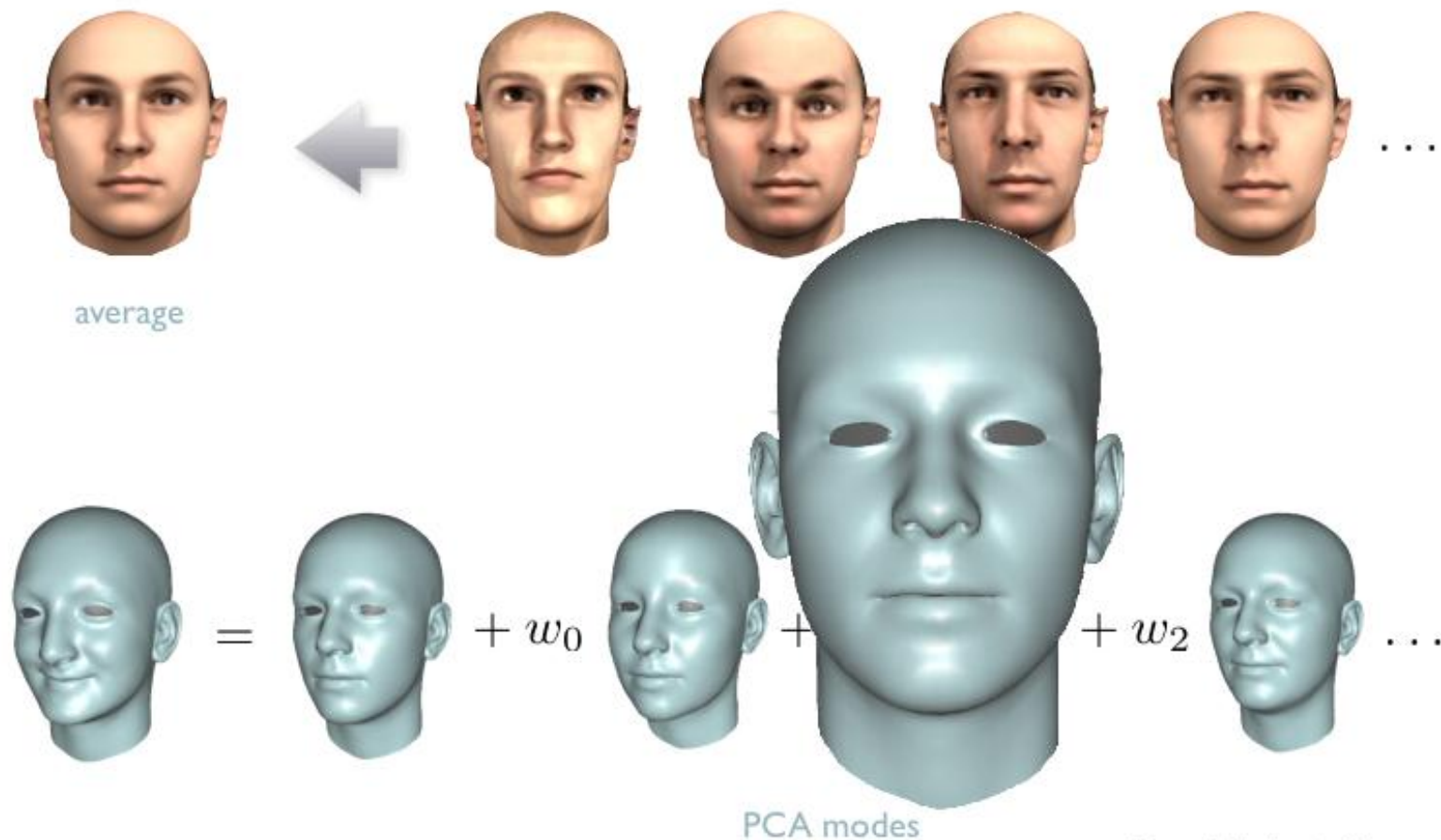
# Non-Rigid ICP + PCA

# Expression Prior

# Real-time Facial Tracking

# Building Expression Space



tracked template                    input scan

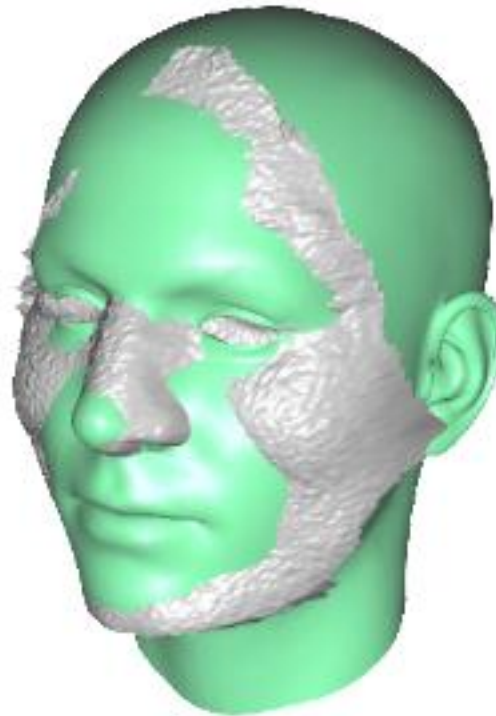# Building Expression Space



Principal Component Analysis

$$= \quad +w_1 \quad +w_2 \quad +w_3 \quad +w_4$$
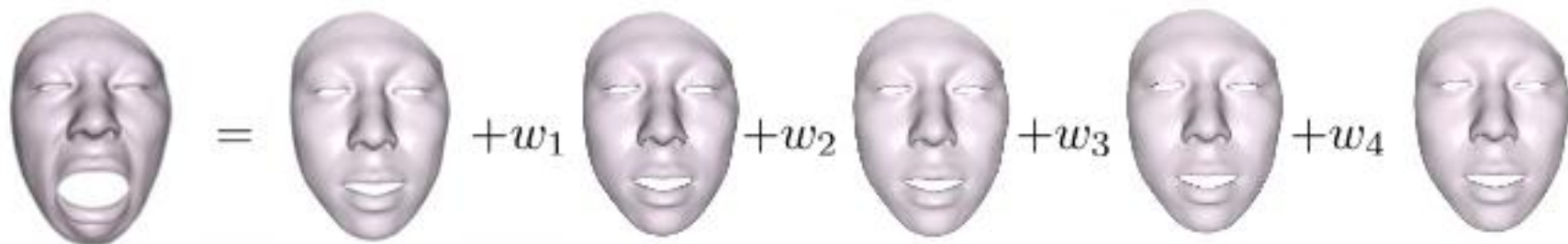
# Example-Based Facial Rigging

# Blendshape Animation
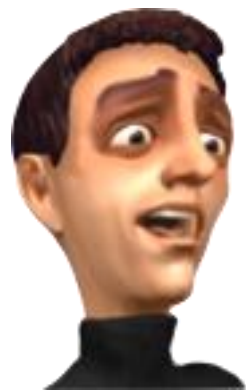
blending weights

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

laughing

neutral face

blendshapes

# Blendshape Animation

# Expression Transfer

prior
blendshapes



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

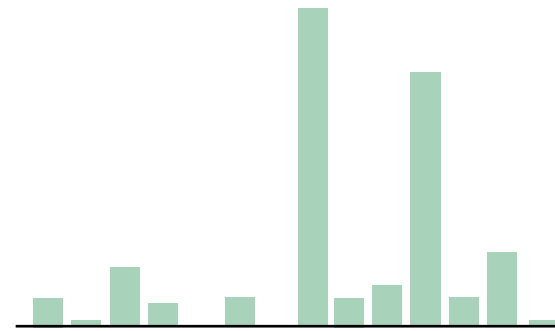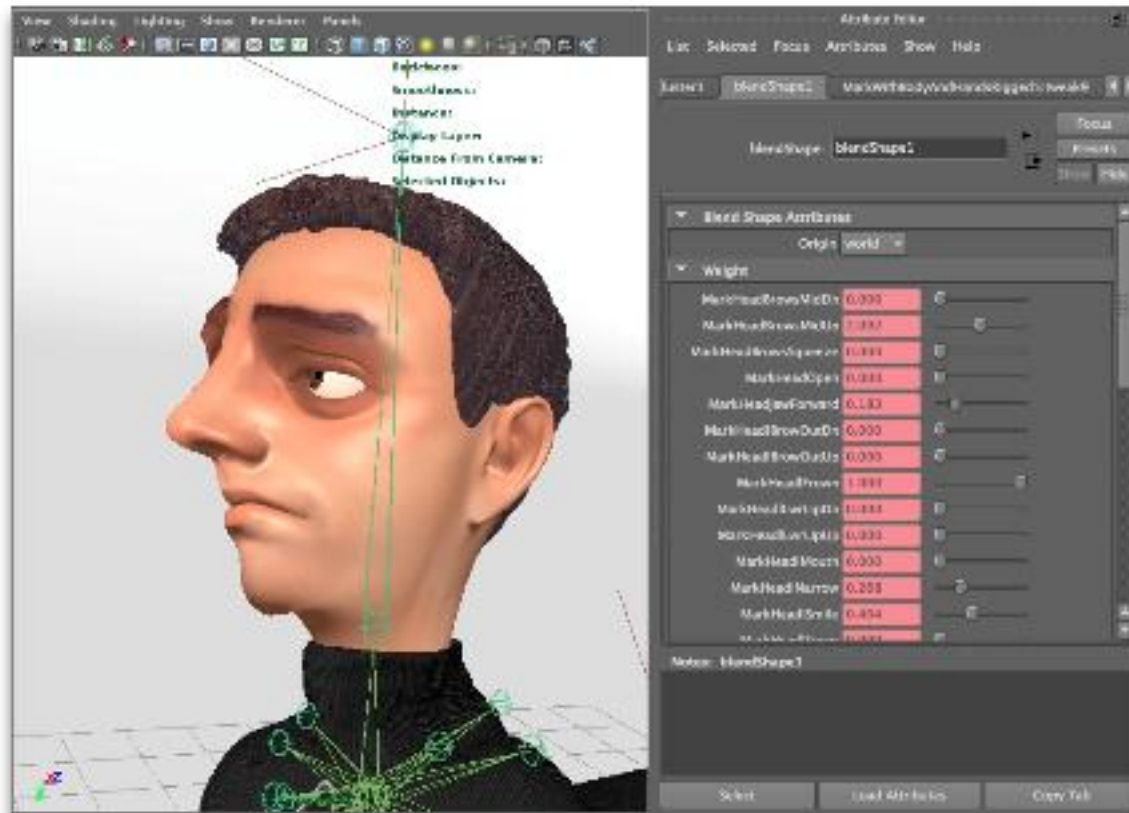reconstructed
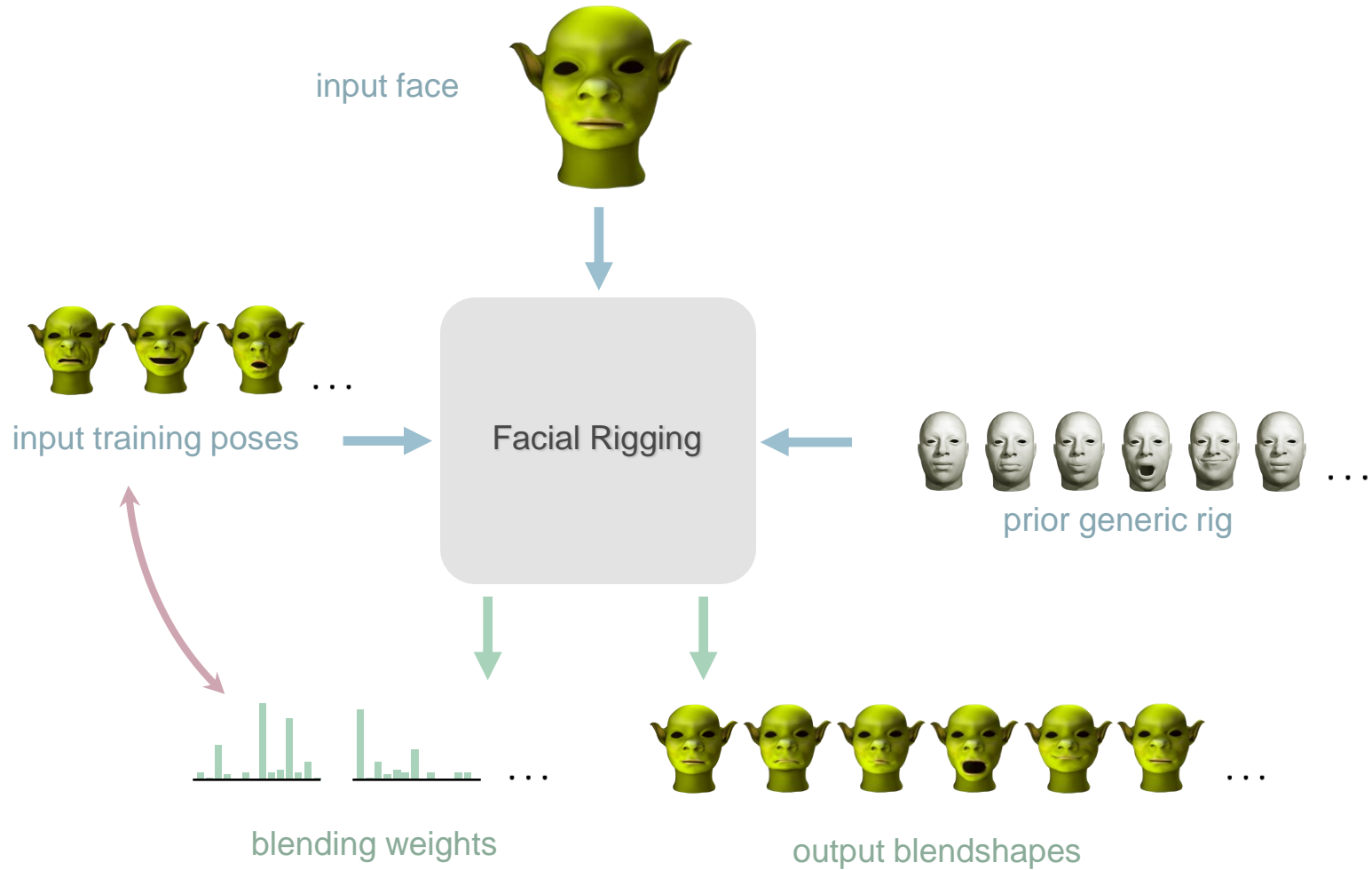blendshapes

# Problems



prior       expression transfer       ground truth

# Example-Based Facial Rigging



input face

input training poses

Facial Rigging

prior generic rig

blending weights

output blendshapes

# Bilinear Problem



input face

input examples

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

blending weights

output blendshapes
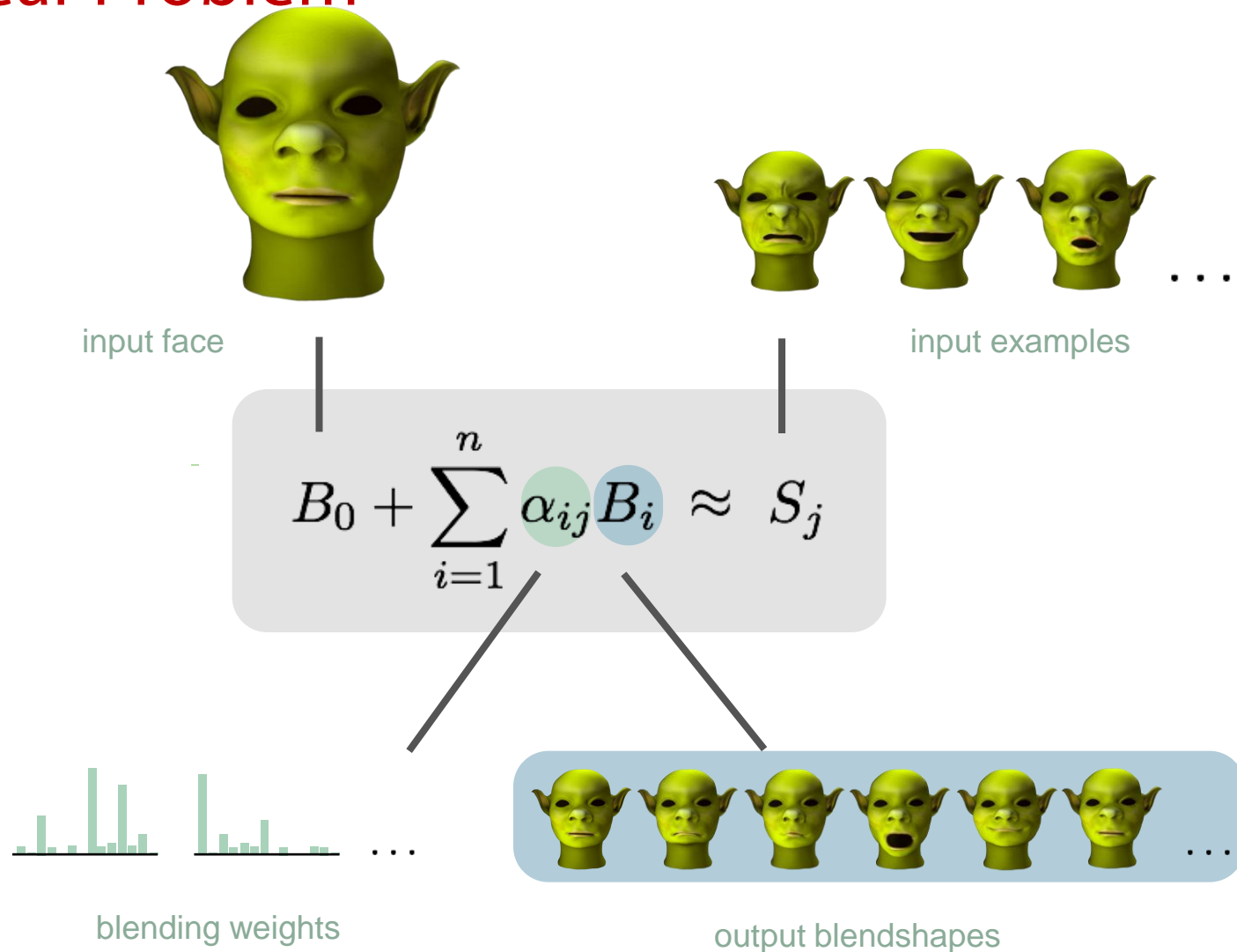
# Decoupled Optimization

Step A

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



Step B

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

# Results



prior | without examples | with 6 examples | input example

whistle

surprise
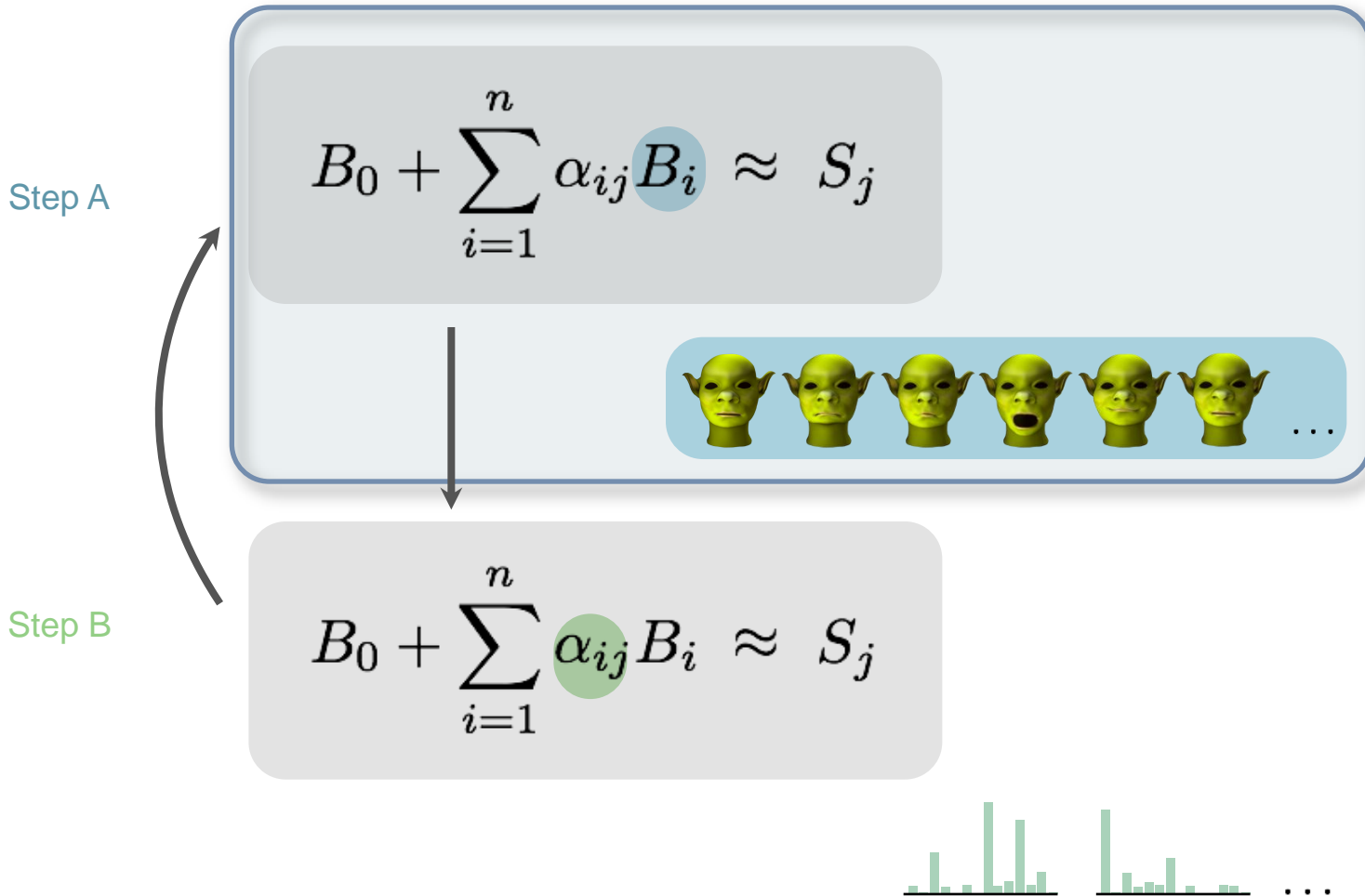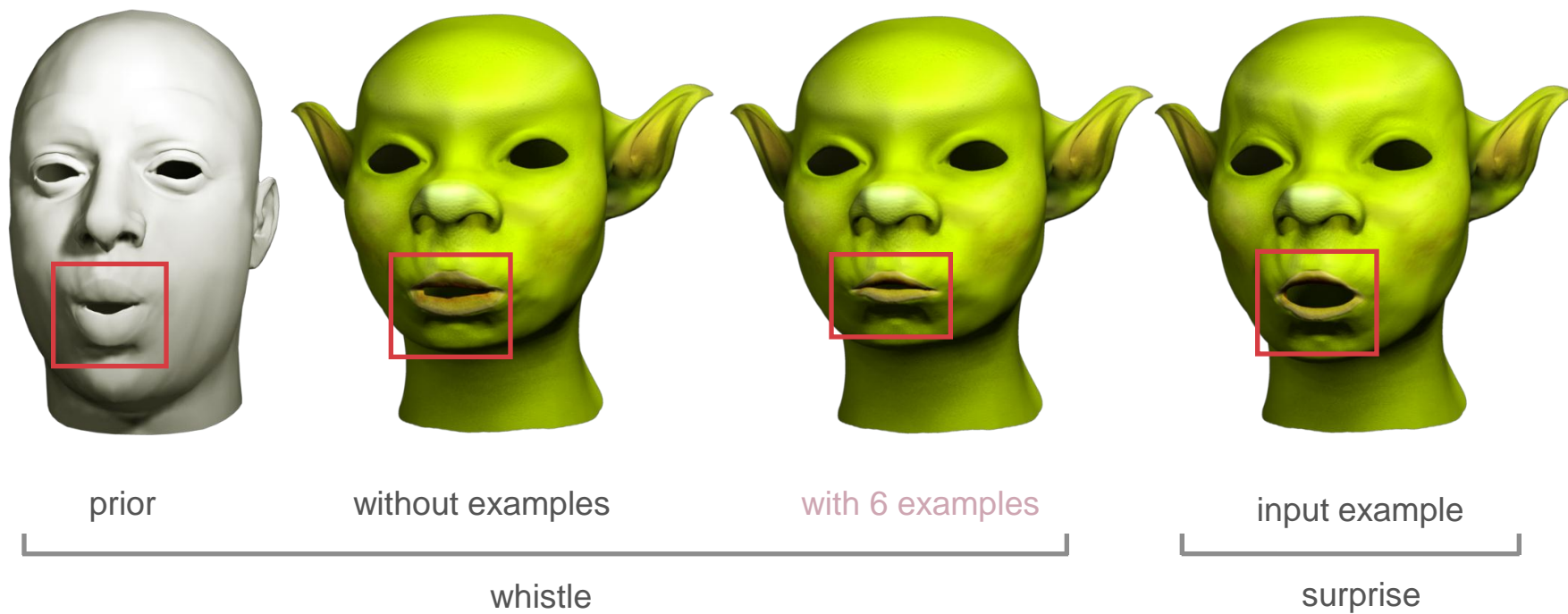
# Directable Facial Tracking

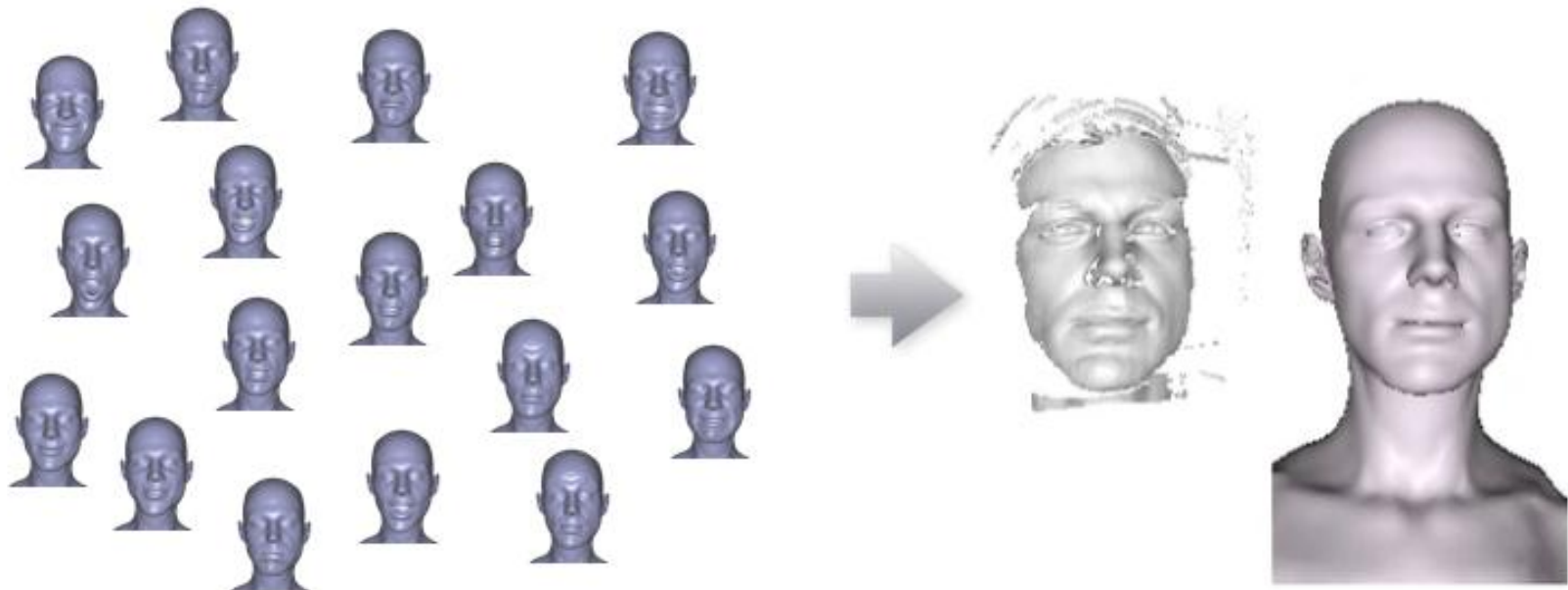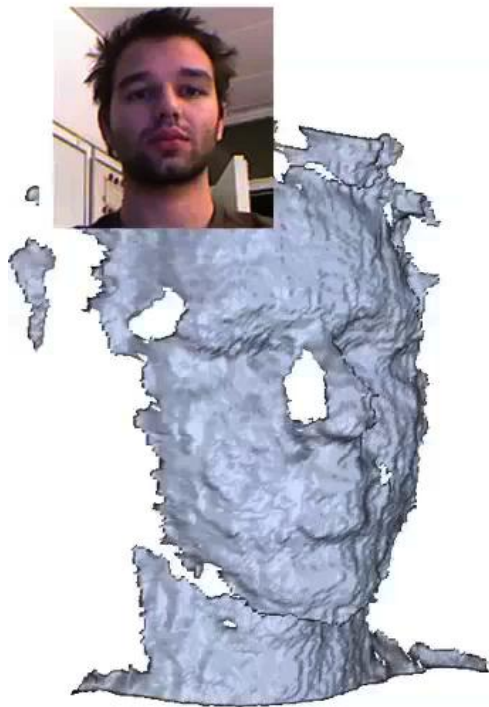# Blendshapes for Tracking

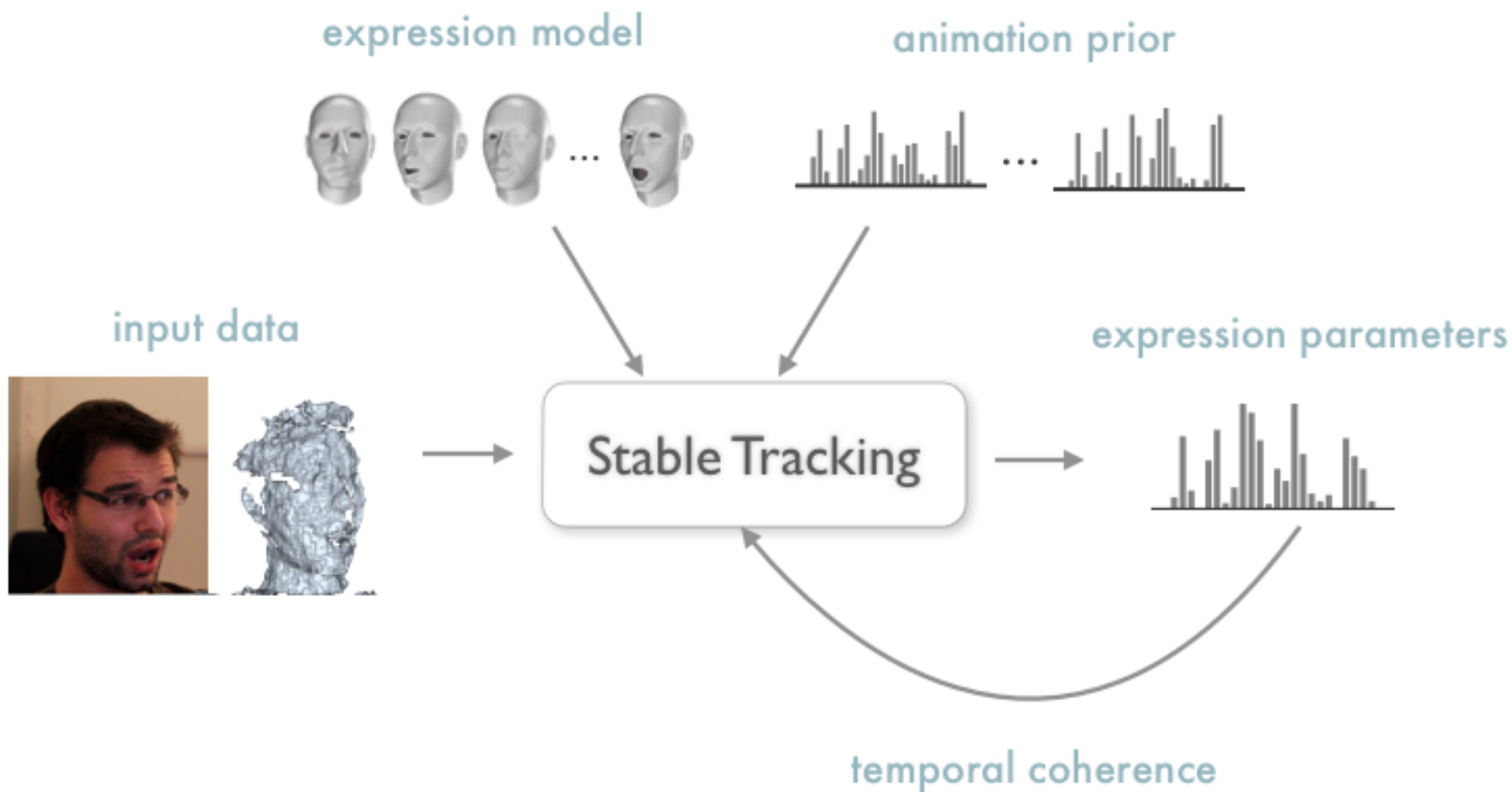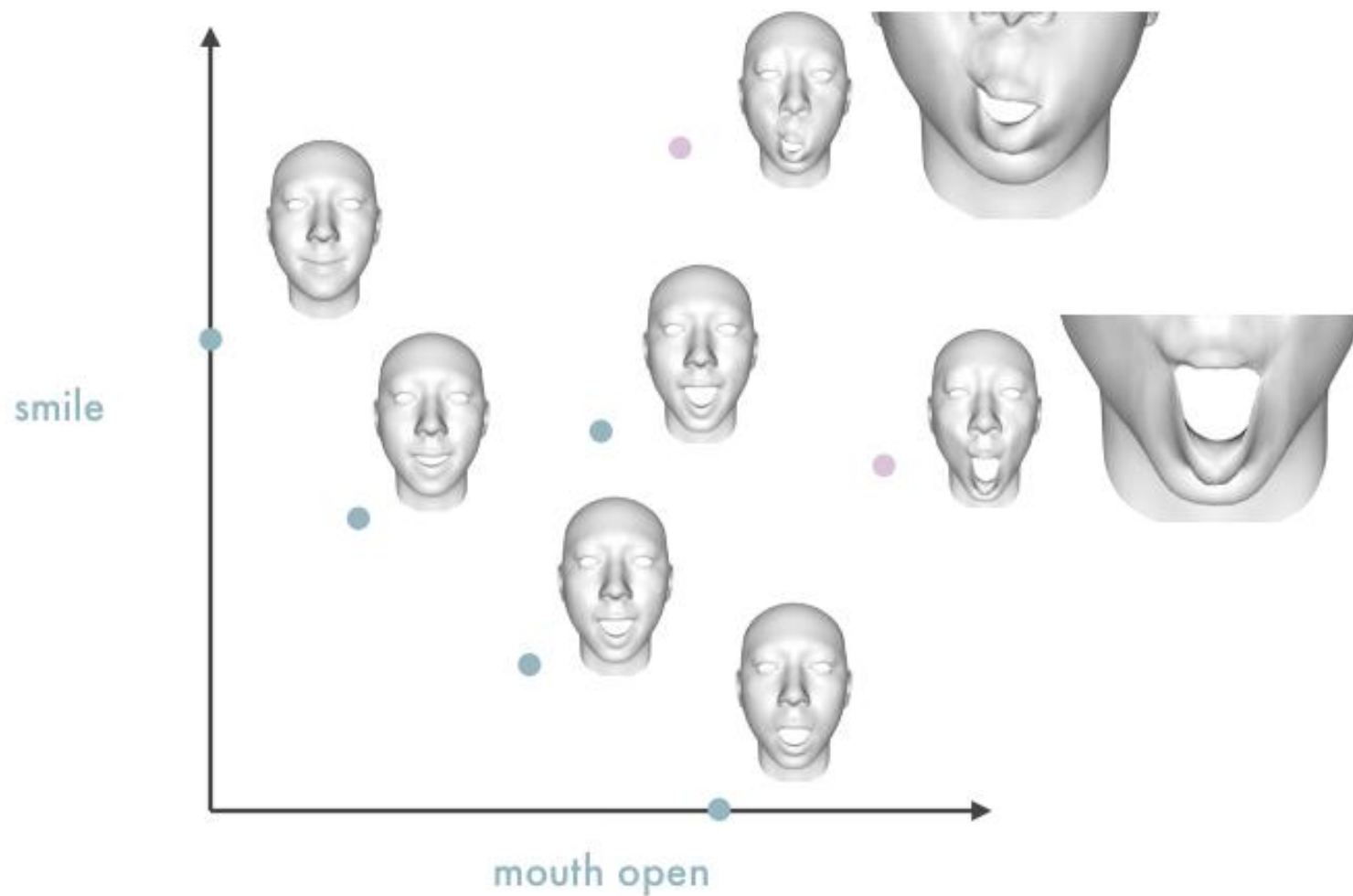# Probabilistic Animation Prior

# Noisy Input
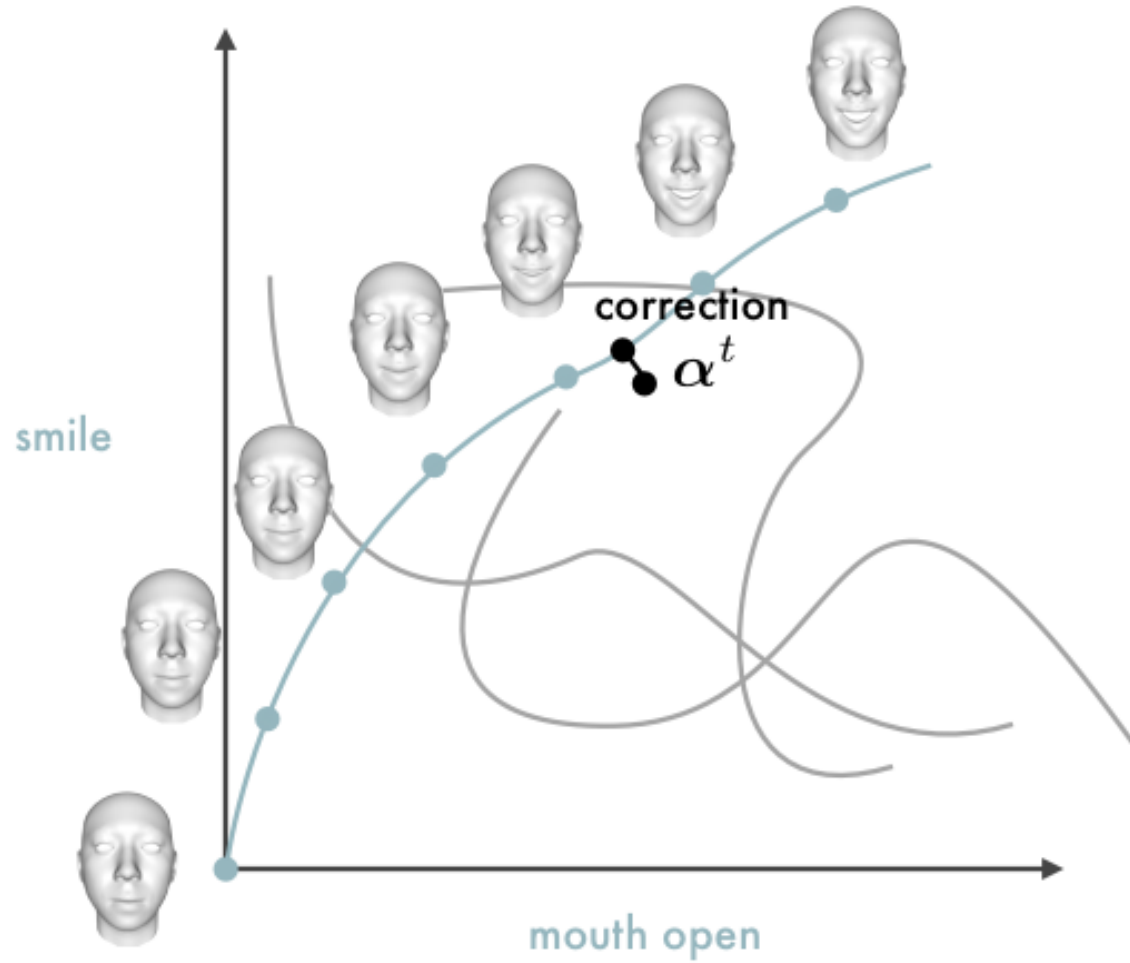


input
scans

tracking

goal

# Performance-Based Animation Pipeline

# N-Dim Expression Space

# Animation Manifold
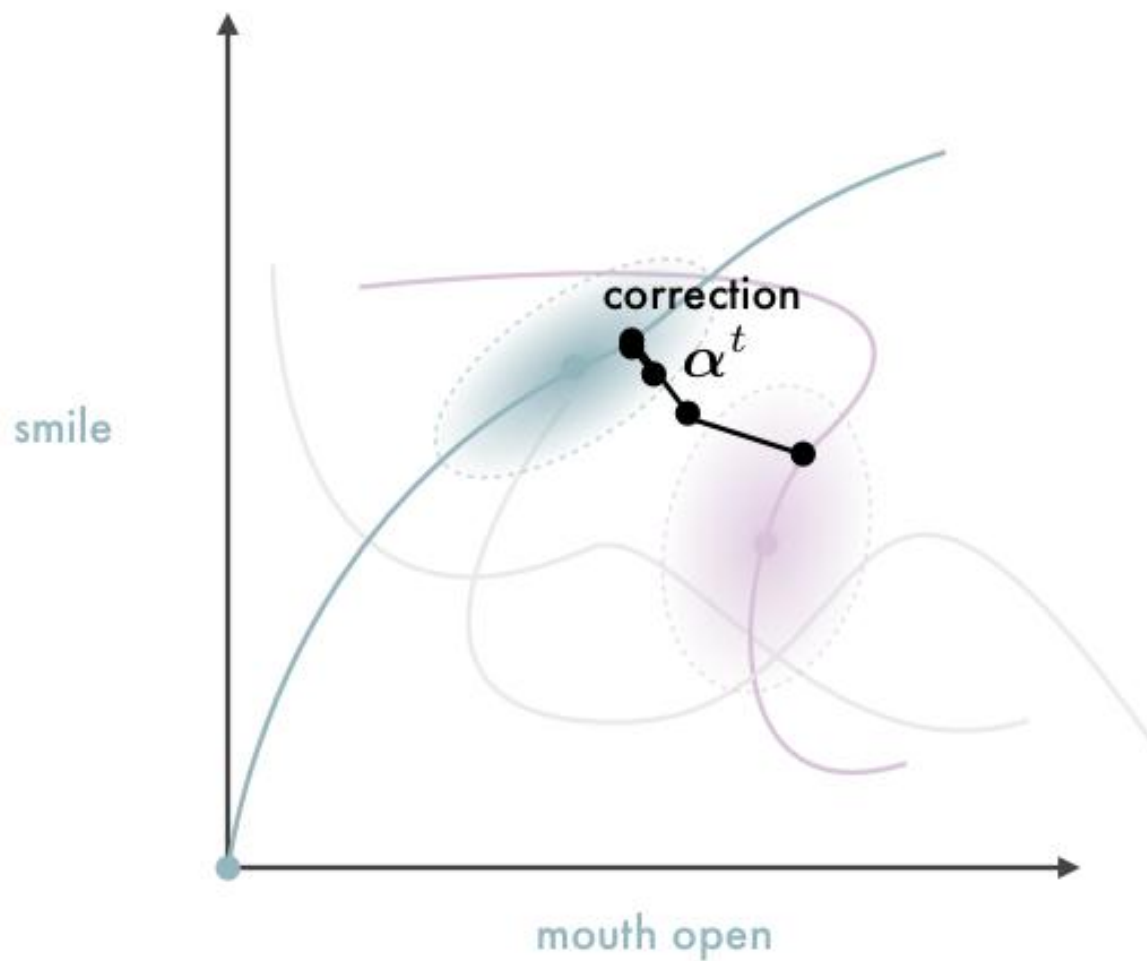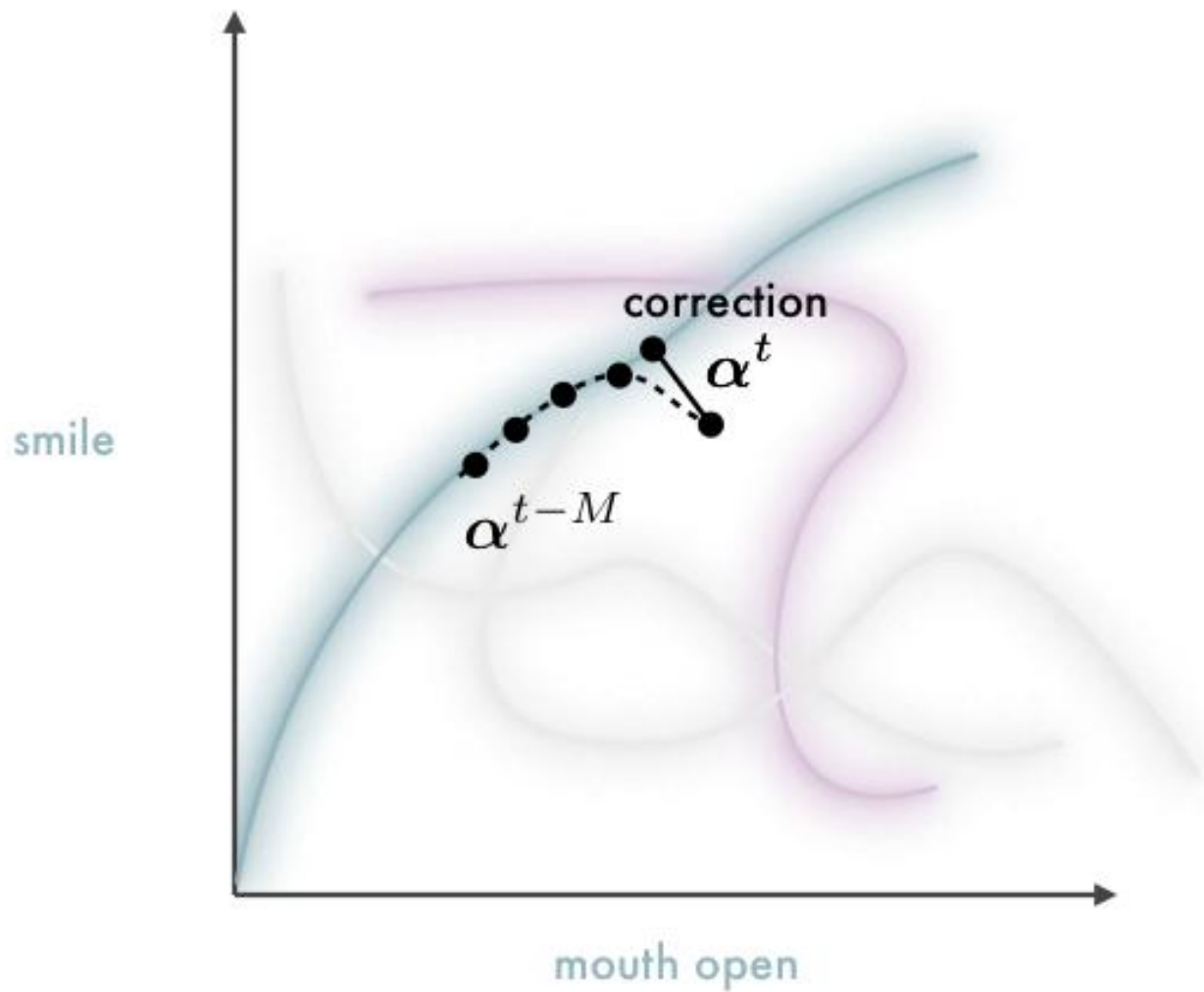
# Probabilistic Expression Prior

# Probabilistic Animation Prior

# Temporal Joint Probabilistic Distribution
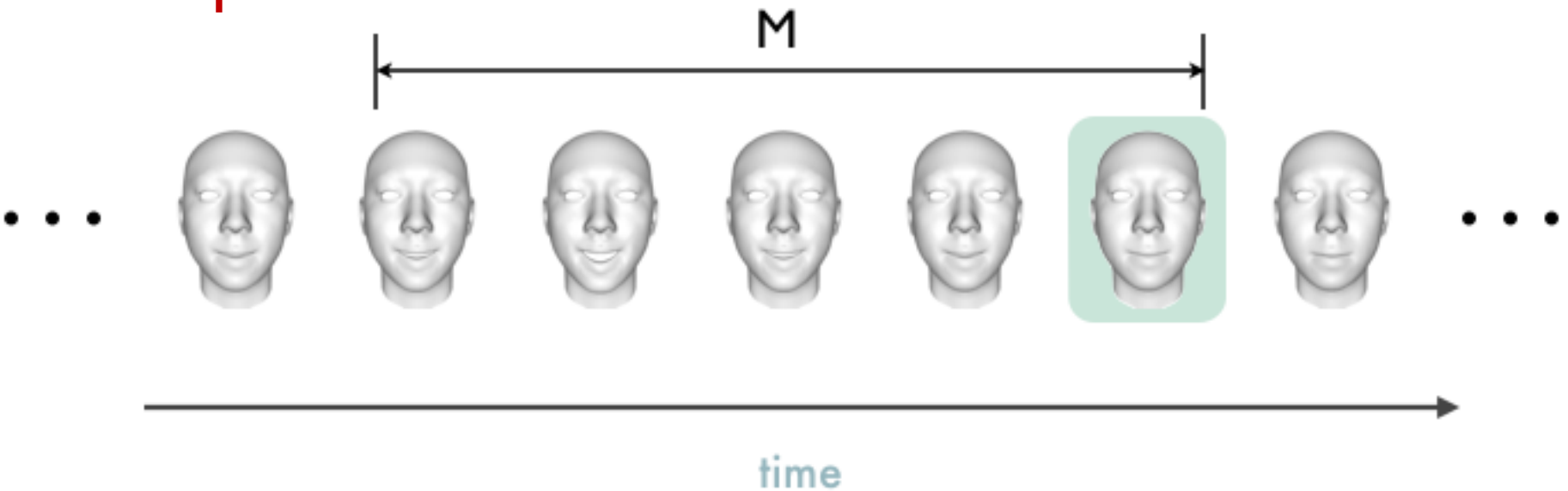


$$p(\boldsymbol{\alpha}^t, .., \boldsymbol{\alpha}^{t-M}) = \sum_{k=1}^{K} \pi_k \mathcal{N}(\boldsymbol{\alpha}^t, .., \boldsymbol{\alpha}^{t-M} | \boldsymbol{\mu}_k, C_k C_k^T + \sigma_k^2 I).$$

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**



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

**texture**



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

# Live Demo