Performance Testing Using Synthesized and Processed Face Images

May 5, 2016

Agenda

- Introduction
- Synthesis Techniques
- Evaluation Methodology & Results
- Example Images
- Q & A

Introduction

- Biosynthetics are synthetic biometric images – fingerprints, faces, and irises – intended for use in biometric system testing
- Support generation of to 13m synthetic images per dataset
  - 1m face, 2m iris, 10m fingerprint
- Helps integrators, gov't agencies evaluate new or updated algorithms
  - Is algorithm A more accurate than algorithm B in our system?
  - Does the vendor's upgrade improve accuracy and/or speed?
  - How do we test that the vendor's proposed architecture scales?
- Meant to reduce effort, cost, and privacy issues associated with biometric data collection and usage
- Goal is visual acceptability, through there are some tradeoffs at scale
- Work originally funded by DHS SBIR (through 2012), since then has matured into a commercial product

Synthesis Techniques

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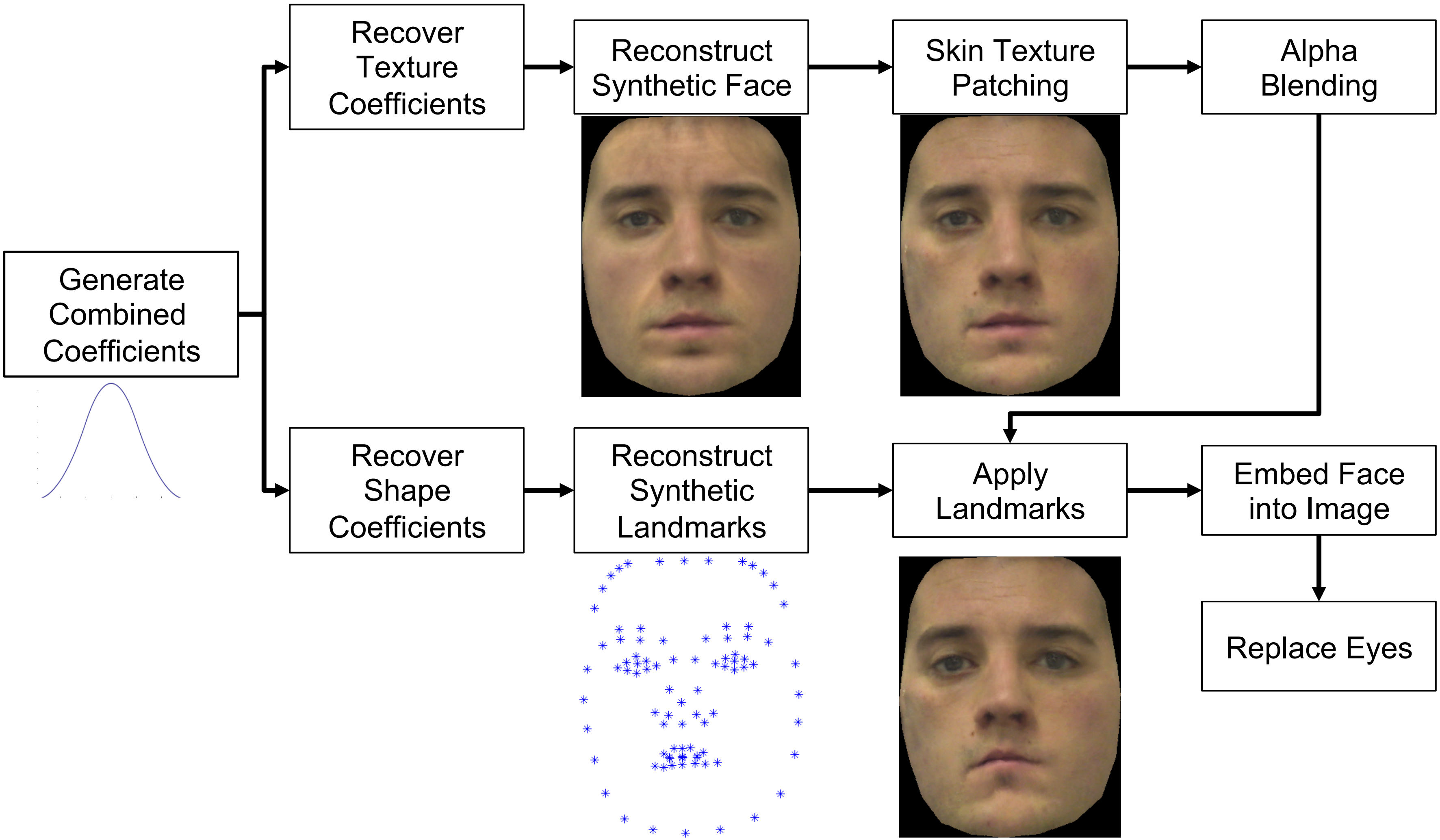
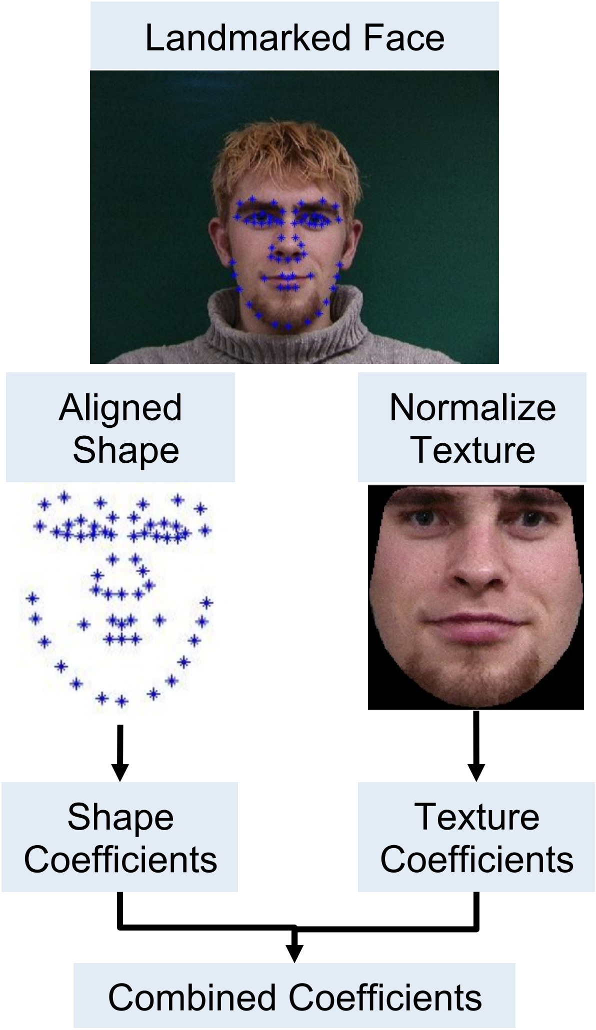
Synthesis Overview



Active Appearance Model (AAM)

- Face images are converted into a parametric representation: shape and texture
- Pre-process shape and texture data
  - Alignment and normalization
- Build statistical models
  - Principal Component Analysis (PCA) coefficients are created for shape and texture
  - Combined coefficients are created from shape and texture coefficients
  - Model is built from combined coefficients of all training images
- Generate coefficients from model
  - Synthetic coefficients are sampled from model
  - Reconstruction reverses the parameterization (coefficients → face image)



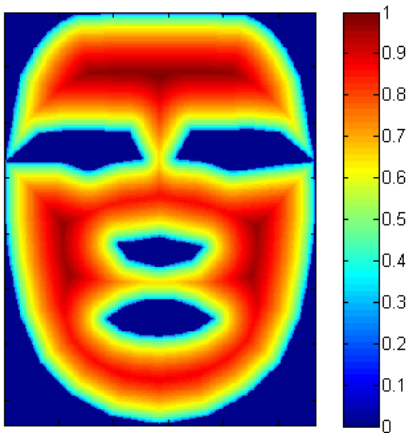
Skin Texture Patching

- Patching introduces variation in skin texture by using the seamless cloning technique of Poisson editing
- Patching occurs across the entire face region with a few exceptions
  - Areas of sharp texture transitions (i.e. eyes and mouth) were prone to be inaccurate, creating visual artifacts
- Patches, or square regions of skin texture, are selected by finding the “best” skin patch in a set of random patches
  - Patch with the smallest mean square error is the best fit
- Process is repeated till all of the face region has been patched

Original Patching Poisson Editing

Alpha Blending

- Alpha blending is a technique that transitions one face (synthetic) into another face (chassis) via varying weighting
  - Chassis is the host image that the synthetic face is embedded into
- Weights are distributed gradually so that pixel transitions may be smooth
- Improves the visual appearance of synthetic face images by reducing sharp transitions



Alpha Mask

Before Alpha Blending

After Alpha Blending

Eye Replacement

- Generating faces through AAM synthesis sometimes creates ill-defined or faded eyes
- Eye replacement is the process of embedding different eyes into the synthetic image to improve the visual appearance
- Eyes from the chassis image or any training image can be used to replace the synthetic eyes
- Additional adjustments such as translation, scaling, and rotation are applied to the eyes

Chassis or Training Face

Synthetic Face

Synthetic Face with Eye Replacement

Evaluation Methodology & Results

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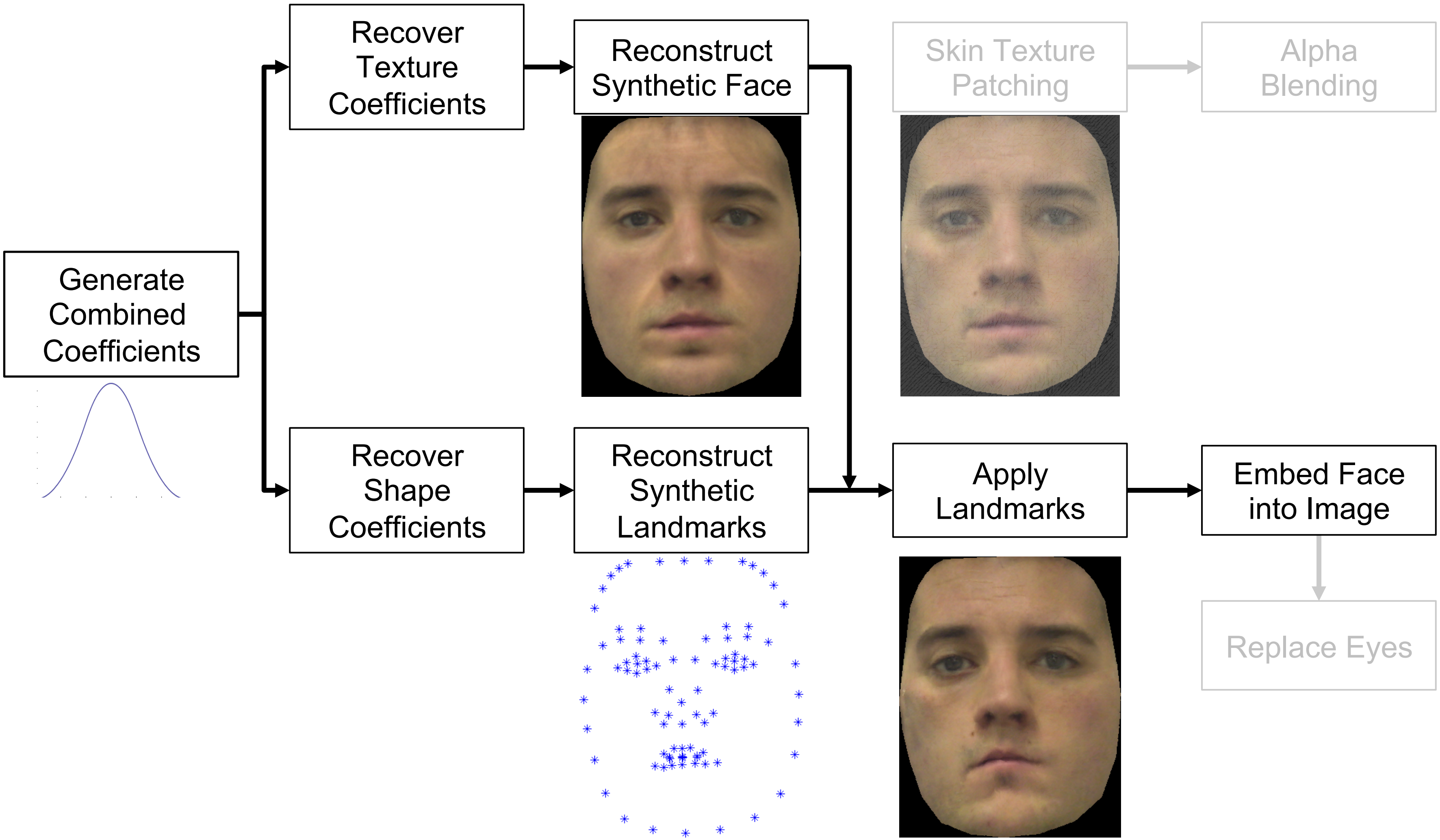
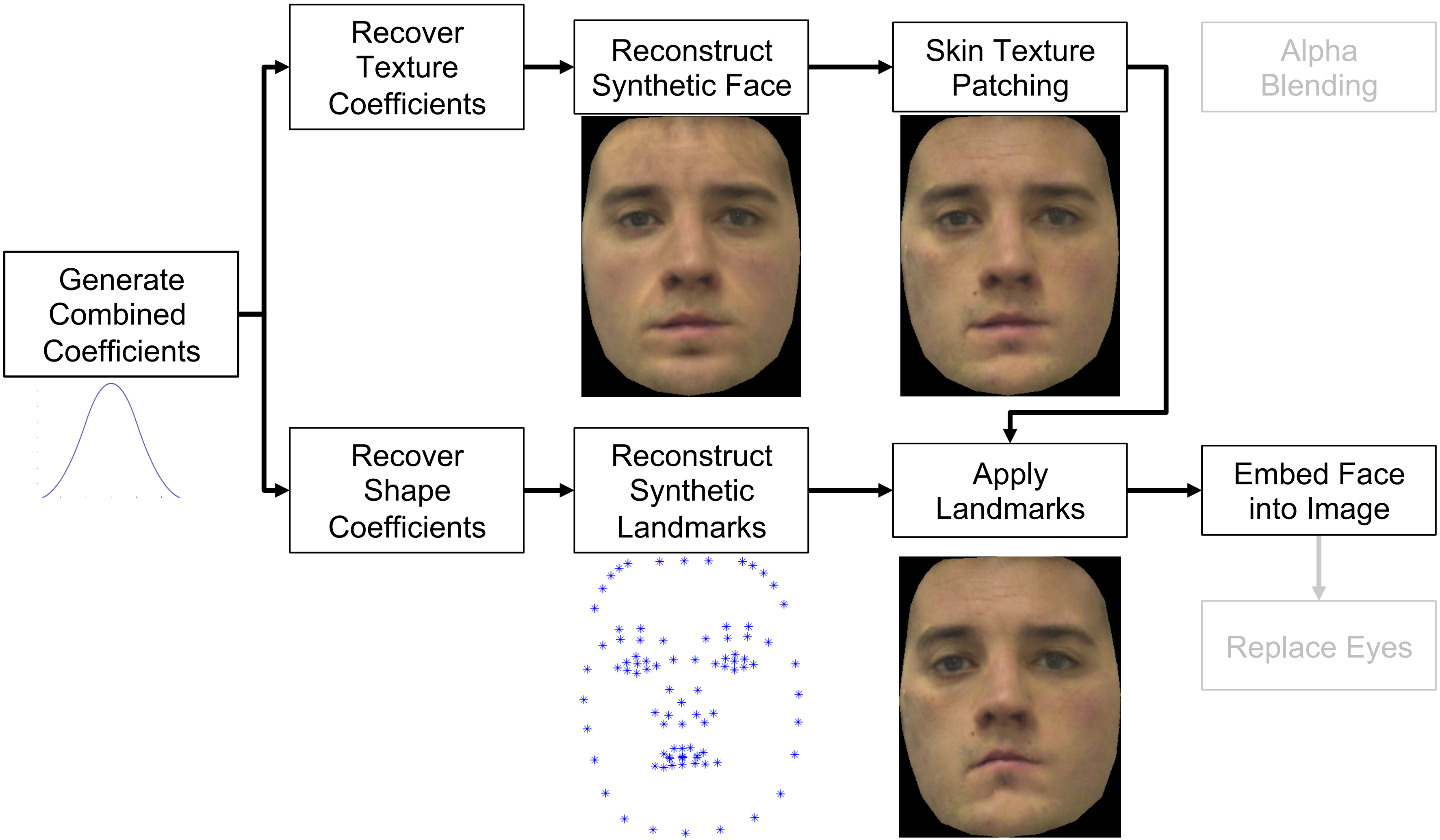
Methodology

- False match rate (FMR) is the proportion of impostor comparisons that are falsely, or incorrectly, matched
- Baseline FMR is produced by matching **real** probe images against **real** gallery images
- Synthetic FMR is produced by matching **synthetic** probe images against **real** gallery images
- Three "stages" of synthetic images are generated where each stage builds on top of the previous
  - Stage 1: Synthesis with AAM modeling
  - Stage 2: Synthesis with AAM modeling and patching
  - Stage 3: Synthesis with AAM modeling, patching, alpha blending and eye replacement
- 50 synthetic probes and 2000 gallery subjects were evaluated

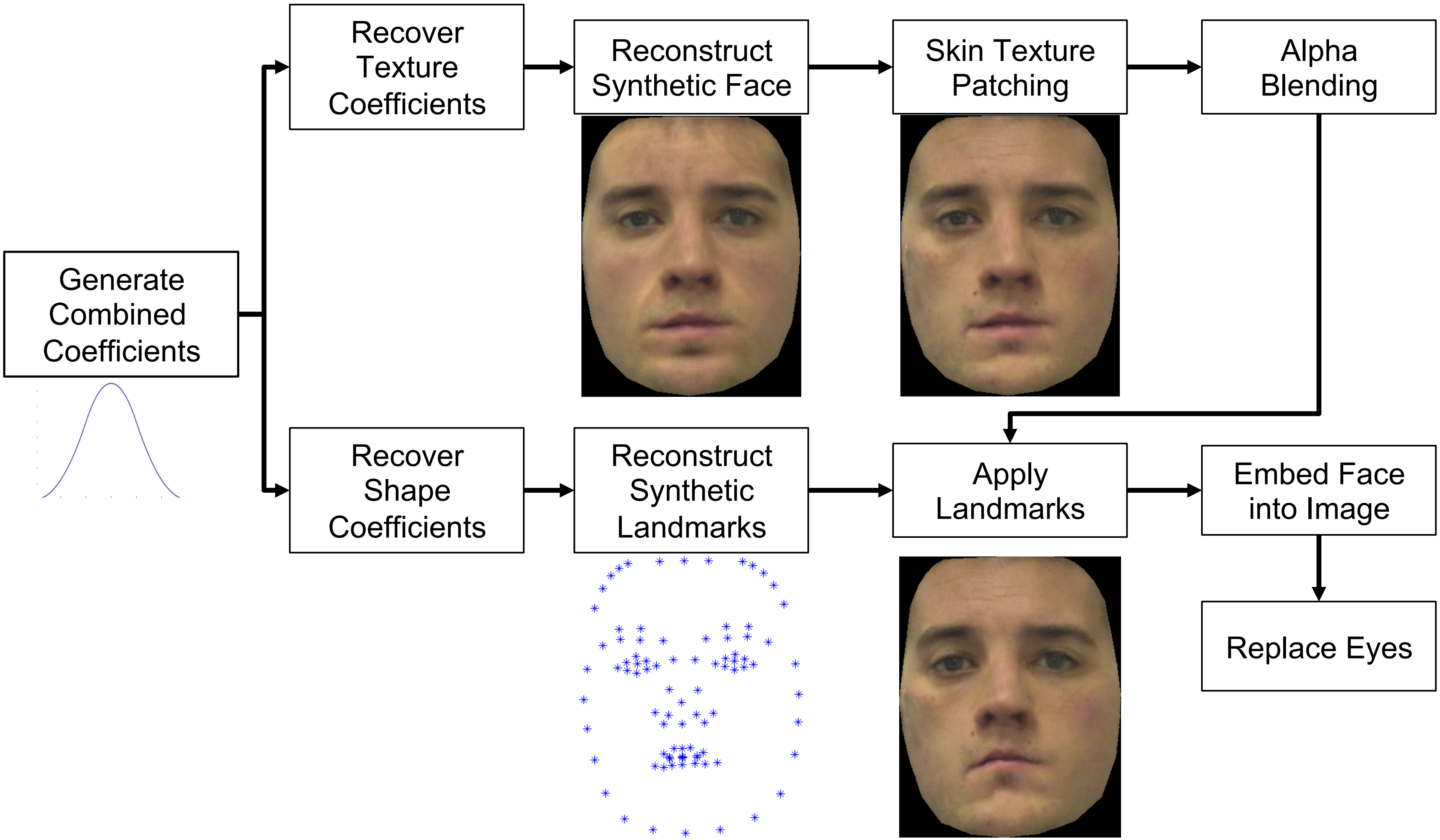
Stage 1 Synthesis



Stage 2 Synthesis



Stage 3 Synthesis



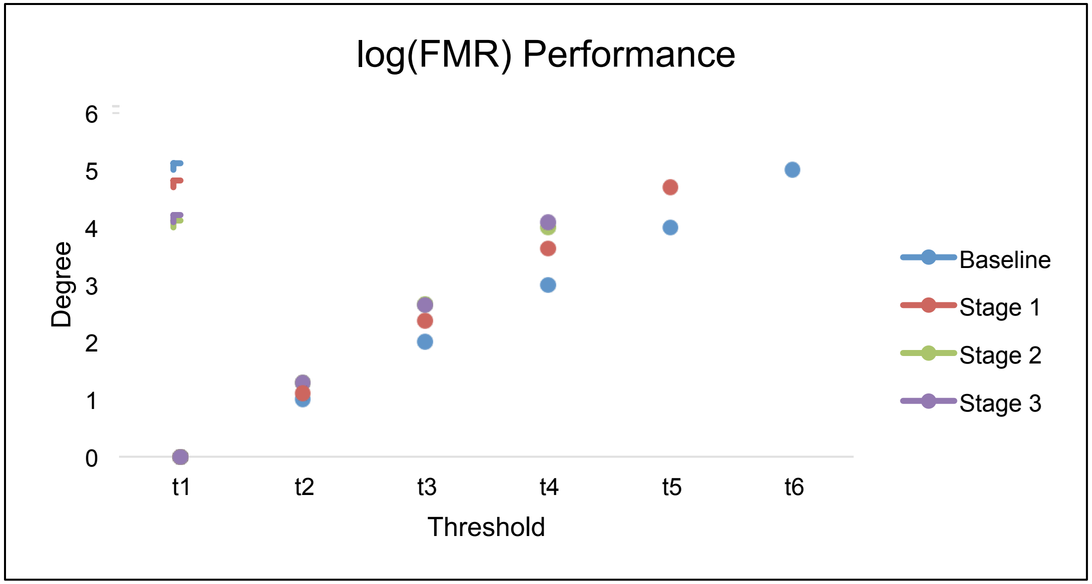
FMR Performance

Threshold	Baseline	Stage 1	Stage 2	Stage 3
t_2	10.08871%	7.92863%	5.17757%	5.21352%
t_3	1.00207%	0.43103%	0.21602%	0.22602%
t_4	0.10001%	0.02300%	0.01000%	0.00800%
t_5	0.01000%	0.00200%	0.00000%	0.00000%
t_6	0.00100%	0.00000%	0.00000%	0.00000%

- Adding visual improvements lowers FMR at stricter thresholds
- Synthetic images are reliable in producing unique identities even with visual improvements
- Further development is necessary to produce visually acceptable synthetic images that maintain realistic FMR behavior across all thresholds

Logarithm of FMR Performance

- The logarithm of FMR computes the degree of the FMR
  - The logarithm of 0% FMR is undefined, therefore Stage 1-3 have shorter curves than Baseline

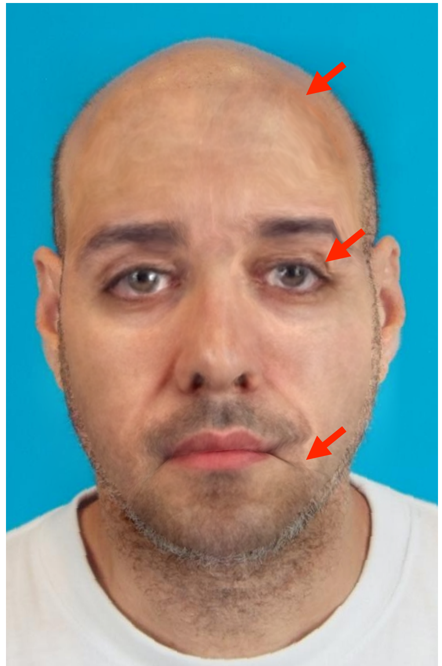


- The degree for all curves are roughly the same between t_1 and t_2
- Deviation from baseline begins at t_3 and continues to increase till t_5
- Stage 2 and 3 perform similarly, where Stage 3 is slightly higher

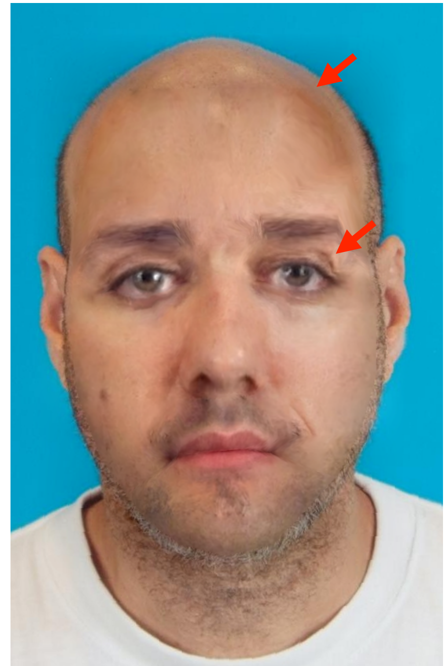
Example Images

Example 1

Baseline



Stage 1

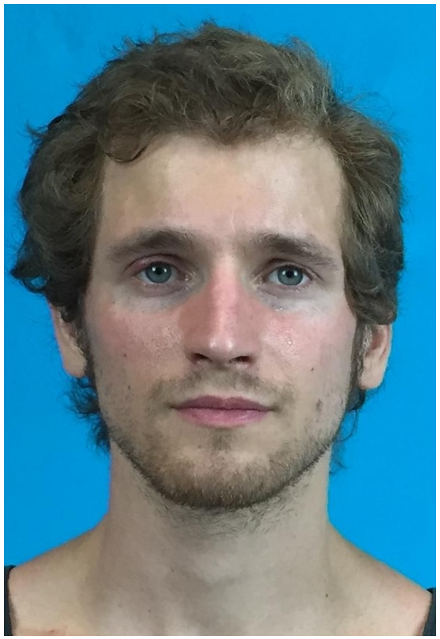


Stage 2

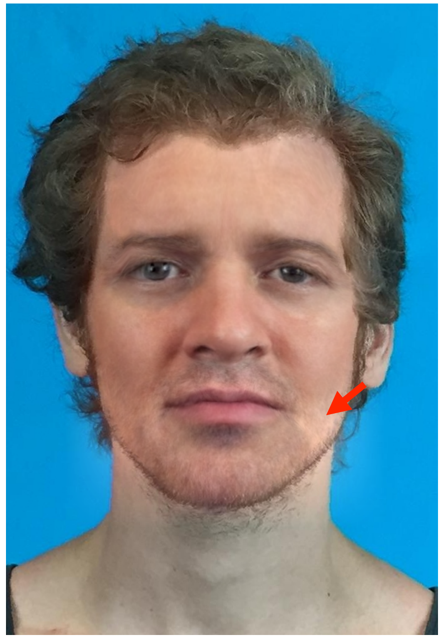
Stage 3

Location of Visual Artifacts

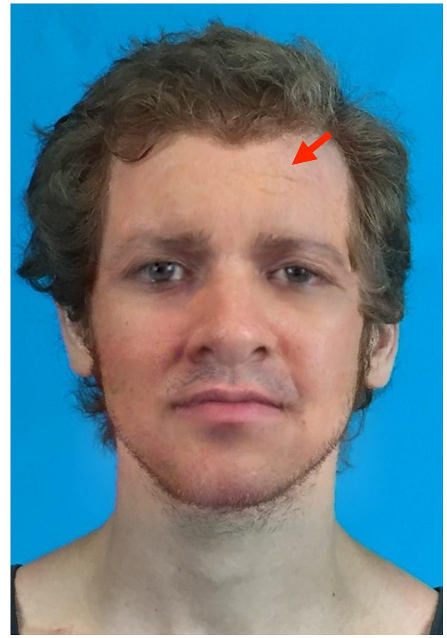
Example 2



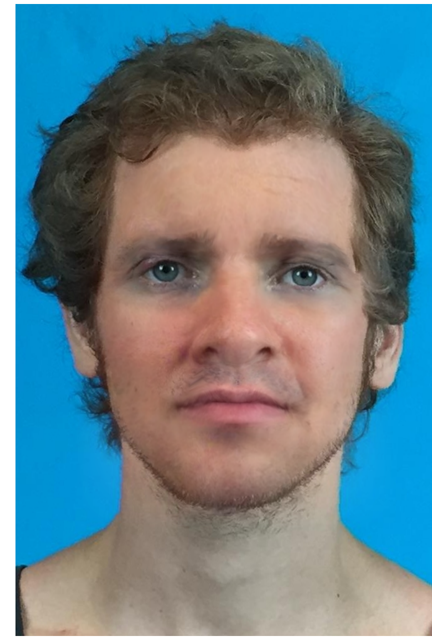
Baseline



Stage 1



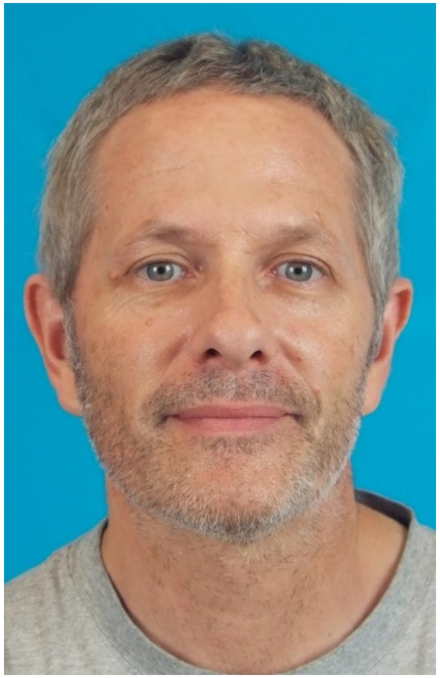
Stage 2



Stage 3

Location of Visual Artifacts

Example 3



Baseline

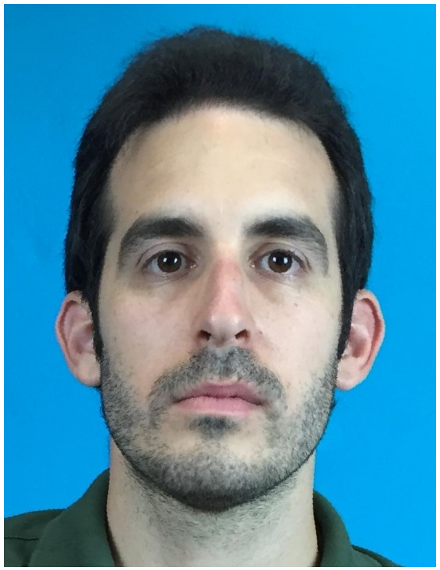
Stage 1

Stage 2

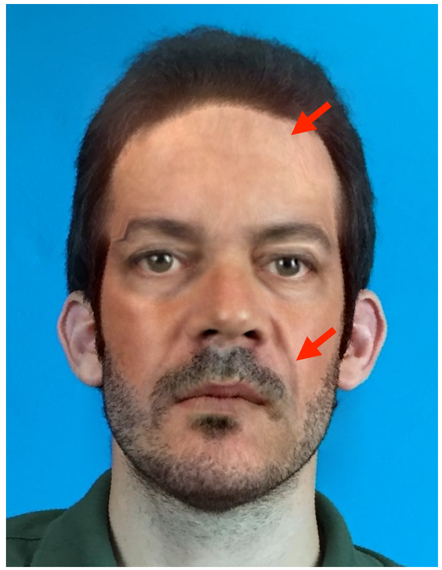
Stage 3

Location of Visual Artifacts

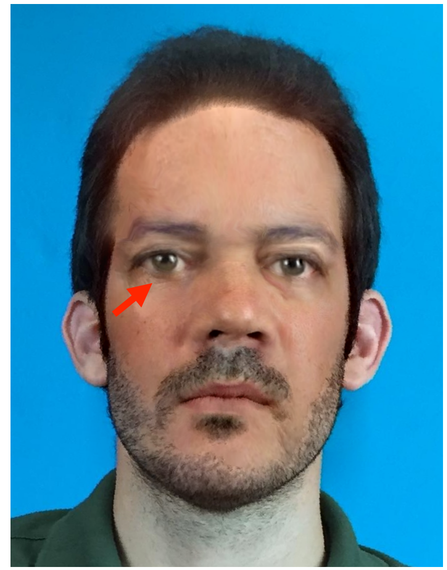
Example 4



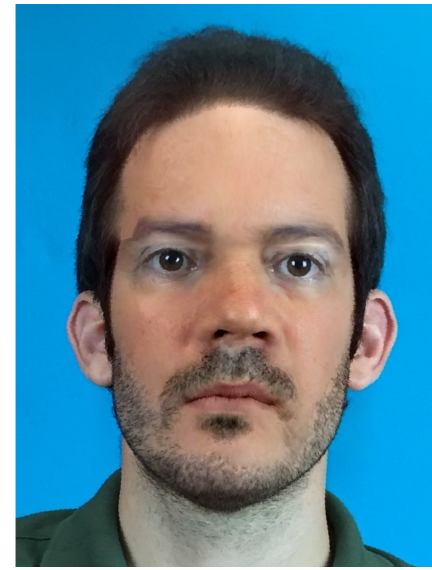
Baseline



Stage 1



Stage 2



Stage 3

Location of Visual Artifacts

Q & A

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