Landmark Detection and 3D Face Reconstruction using Modern C++

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BMVA

UNIVERSITY OF SURREY

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Landmark detection and 3D face reconstruction using modern C++

- We aim to fill two (or three) gaps:
  - Open & available **3D** face models and fitting algorithms
  - Easy-to-use, modern C++ code for above
- Bonus:
  - Reproducible research

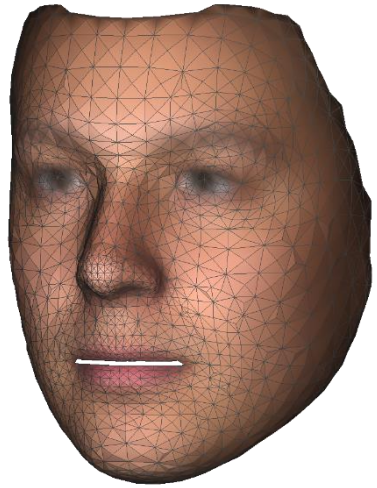
3D morphable face models & fitting

- 3D face models have some desireable properties
  - Shape and pose are modelled separately (i.e. camera model, and shape model)
  - Depth information

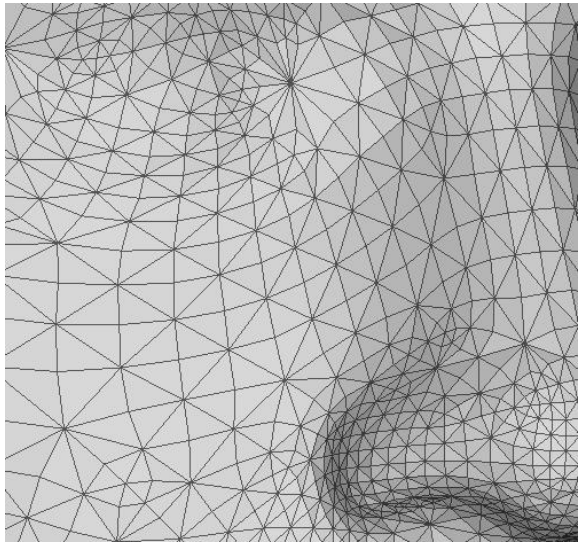
- Usually harder to train and use than other (e.g. 2D) methods
  - 3D scans instead of images, dense 3D-3D registration, usually much more parameters during fitting (shape, pose, albedo, light)

- Not many models are available, even less freely, and even less with fitting code
  - Most well known: BFM from T. Vetter et al., *A 3D Face Model for Pose and Illumination Invariant Face Recognition*, AVSS 2009

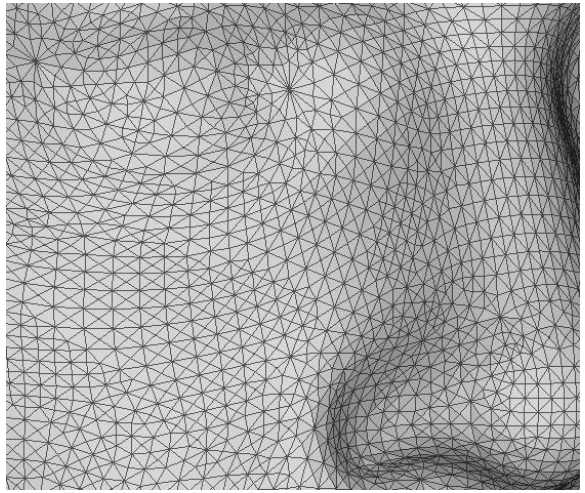
The Surrey 3D Morphable Face Model



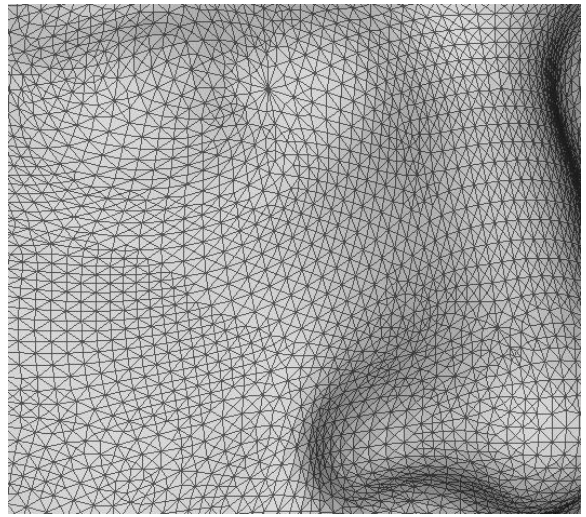
- PCA model of shape and colour (albedo)
- Built from 170 3D scans with diverse ethnicity
- 3 different resolution levels
- Metadata (texture coordinates, landmark definitions, ...)



3448 vertices

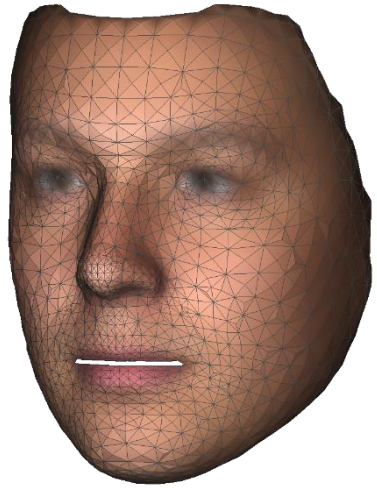


16759 vertices



29587 vertices

The Surrey 3D Morphable Face Model



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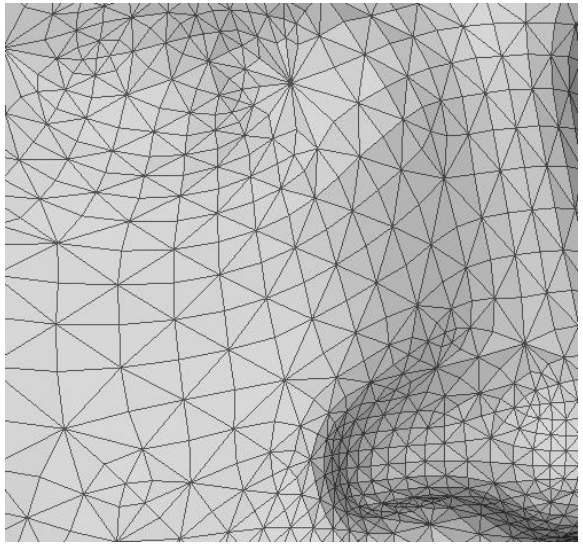


3448 vertices

- The low-resolution shape-only model is available directly with the software on GitHub
- Higher resolutions & full model via University licencing

Along with the model there's a lightweight modern C++ framework to use the model and perform basic shape fitting tasks

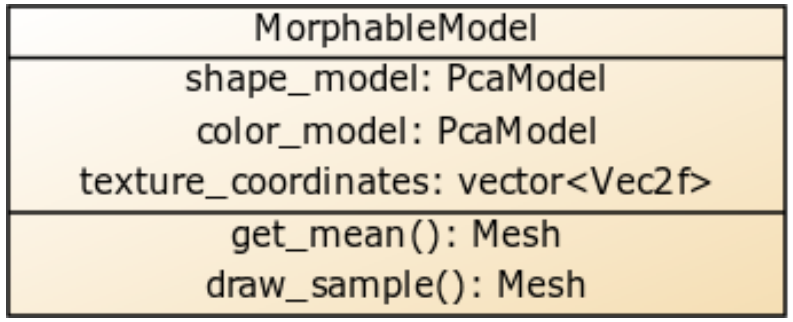
https://github.com/patrikhuber/eos

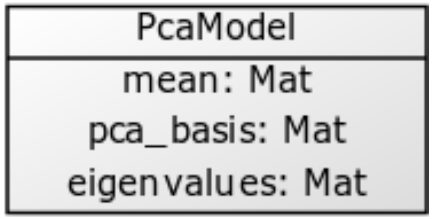
(more after the next slide...)

Modern C++?

- There's not many 3DMM fitting frameworks, even less in C++
  - menpo (Python)
- C++ is a very widely used language in computer vision
  - Speed, cross-platform compatibility, mobile devices, embedded, robots, ...
- C++ has a reputation of being low-level, hard to learn, read, use & maintain, pointers, memory leaks, segmentation faults, ...
  - A lot of the C++ code «out there» looks like that
- ➔ That's not how it should be written nowadays
  - C++ can be as easy and safe as a language like Matlab, while not losing any of its advantages

How does that look like?






```
MorphableModel morphable_model = morphablemodel::load(filename); // loaded using cereal

Mesh mesh = morphable_model.draw_sample(vector<float>{1.0f, 0.0f, -1.0f}, vector<float>());
mesh = morphable_model.draw_sample(/* shape_sigma=1.0f, colour_sigma=1.0f*/);

write_obj(mesh, "out.obj");
```

*All namespaces omitted. Complete example:
https://github.com/patrikhuber/eos/blob/master/examples/fit-model.cpp

Fitting the shape-3DMM

```
vector<Vec2f> image_points;
vector<Vec4f> model_points;

Mat affine_cam = estimate_affine_camera(image_points, model_points);

vector<float> shape_coeffs = fit_shape_to_landmarks_linear(morphable_model, affine_cam,
                                                           image_points, vertex_indices);

Mesh mesh = morphable_model.draw_sample(shape_coeffs, vector<float>());
write_obj(mesh, "out.obj");

Mat texture = extract_texture(mesh, affine_cam, image);
```

supervised descent / cascaded regression

- A generic implementation of SDM
- Learn a series of regressors:

$$\mathbf{R_n}\colon\ \delta\boldsymbol{\theta} = \mathbf{A_n}\mathbf{f}(\mathbf{I}, \boldsymbol{\theta}) + \mathbf{b_n}$$

- $\boldsymbol{\theta}$ are traditionally 2D landmark locations: $\boldsymbol{\theta} = [x_1, \ldots, x_n, y_1, \ldots, y_n]$
  - E.g. X. Xiong & F. De la Torre, *Supervised Descent Method and Its Applications to Face Alignment*

- But it can be anything, for example 3D model parameters:
  - $\boldsymbol{\theta} = [\mathrm{R_x}, \mathrm{R_y}, \mathrm{R_z}, t_x, t_y, t_z, \alpha_0, \alpha_1, \ldots]$
  - Huber et al. 2015, Li et al. 2015

superviseddescent / cascaded regression

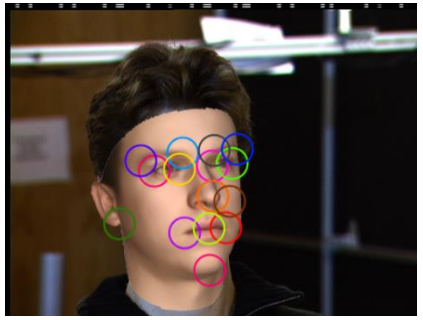
- A generic implementation of SDM
- Learn a series of regressors:

$$\mathbf{R_n}\colon\ \delta\boldsymbol{\theta} = \mathbf{A_n}\mathbf{f}(\mathbf{I}, \boldsymbol{\theta}) + \mathbf{b_n}$$

- Projection $\mathbf{f}(\dots)$ is generic too:
  - Can be HOG feature extraction
  - or involve full 3D model projection: $\delta\boldsymbol{\theta} = \mathbf{A_n}\mathbf{f}(\mathbf{I}, \mathbf{M}, \boldsymbol{\theta}) + \mathbf{b_n}$

Fitting 3D Morphable Models using Local Features

Input image



Model projection using the current parameter estimate $\boldsymbol{\theta}$

Local feature extraction regions

Initialisation from default parameters

The parameter vector $\boldsymbol{\theta} = [r_x, r_y, r_z, t_x, t_y, t_z, \alpha_0, \alpha_1]$ is updated using the learned regressors

ICIP 2015, P. Huber, Z. Feng, W. Christmas, J. Kittler, M. Rätsch

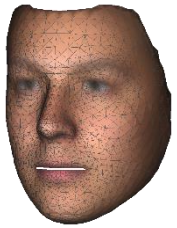
Landmark-detection in 3 lines of code

```
detection_model model = load_detection_model("model.bin");

Mat image = cv::imread("image.png");

vector<Landmark<Vec2f>> landmarks = model.detect(image, Rect(50, 50, 80, 80));
```

*All namespaces omitted for brevity.

Surrey 3D Morphable Face Model and fitting library

superviseddescent library



C++11/14, Fully cross-platform (Windows/Linux/Mac/...)

Header-only

Apache licence

External dependencies: OpenCV core, (Eigen)

https://github.com/patrikhuber/eos

https://github.com/patrikhuber/superviseddescent

Demo

Concluding words

- C++ is an important language for computer vision
  - It's important to learn, use and spread modern best practices
  - ...and have libraries that are easy to use and maintain

- Push research with **3D** face models
  - via open & shared code & models

- superviseddescent – generic cascaded regression library

- Low-resolution 3DMM shape model available in the repo
  - Higher resolutions & full model via University licencing

- eos – 3DMM framework & fitting library

Team

- Zhenhua Feng (Uni Surrey)
- Guosheng Hu (previously Uni Surrey)
- Philipp Kopp (Reutlingen Uni)
- Rafael Tena (previously Uni Surrey)
- Pouria Mortazavian (previously Uni Surrey)
- Willem Koppen (Uni Surrey)
- Michael Grupp (Reutlingen Uni)
- Dr. Matthias Rätsch (Reutlingen Uni)
- Dr. William Christmas (Uni Surrey)
- Prof. Josef Kittler (Uni Surrey)

References

- Own & related publications:
  - **A Multiresolution 3D Morphable Face Model and Fitting Framework**, P. Huber, G. Hu, R. Tena, P. Mortazavian, W. Koppen, W. Christmas, M. Rätsch, J. Kittler, *in peer review (2015)*
  - **Fitting 3D Morphable Models using Local Features**, P. Huber, Z. Feng, W. Christmas, J. Kittler, M. Rätsch, *ICIP 2015*
  - **Random Cascaded-Regression Copse for Robust Facial Landmark Detection**, Z. Feng, P. Huber, J. Kittler, W. Christmas, X.J. Wu, *IEEE Signal Processing Letters, 2015*
  - **Supervised Descent Method and Its Applications to Face Alignment**, X. Xiong and F. De la Torre, *CVPR 2013*

Thank you!

Questions?

Suggestions, comments and contributions very welcome! (email me or open a GitHub issue)

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