GaFF: A Genetic Algorithm for Face Fitting (Work in Progress).

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Project Aims

Objective Create a system to accurately estimate the three-dimensional shape of a human head from a single image.

Fully Automated. We aim to avoid manual interaction, common in most current methods, such as manually specifying landmarks on the image.

Avoid Local Minima. Gradient Descent methods are prone to local-minima problems. This can result in a poor approximation of shape.

Proposed solution: ***Using a Genetic Algorithm.***

Model

We parametrise the space of human head shapes using a 3D Morphable Model [BV99]. We use 187 registered 3D head scans to build a PCA model taking the top 40 eigen-vectors.

Error Function

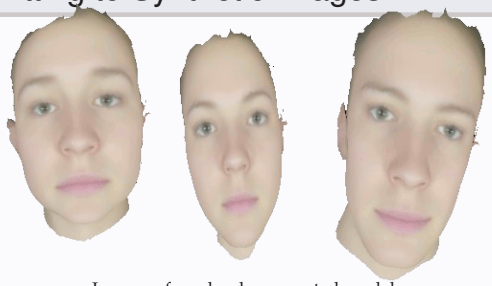
We attempt to minimise the L^2-norm between a rendered image ($\mathcal{M}$) of the Morphable Model with shape and pose parameters $\mathbf{p}$ and a target image, $\mathcal{I}$.

$$\chi^2 = \sum_{\mathbf{x}\in\Omega} (\mathcal{M}(\mathbf{p}) - \mathcal{I})^2$$

Proposed Algorithm

Require: A Morphable Model parametrised using $\mathbf{p} = \{p_1, \ldots, p_n\}$
Require: A error function $f(\mathbf{f}) : \mathcal{D} \mapsto \Re$
  $\mathbf{P}$ = a set of m sample points $\mathbf{s}_i, i = 1 \ldots m$ from $\mathcal{D}$
  repeat
    Set $\mathbf{P}_{(l)} \in \mathbf{P}$ to be the subset of $\mathbf{P}$ containing the l smallest values of $f(\mathbf{p}_i)$.
    for $k = 1$ to m **do** {Create m new 'children'}
      Choose a pair of samples from $\mathbf{P}_{(l)}$ at random and denote $\mathbf{p}_i$ and $\mathbf{p}_j$, where $i \neq j$.
      for $l = 1$ to n **do**
        Set parameter from random parent.
      end for
      for $l = 1$ to n **do**
        Small probability that the parameter $\mathbf{C}_{k,l}$ is altered by a small amount
      end for
    end for
  until $\Delta\mathbf{u} < \epsilon$

Fitting to Synthetic Images



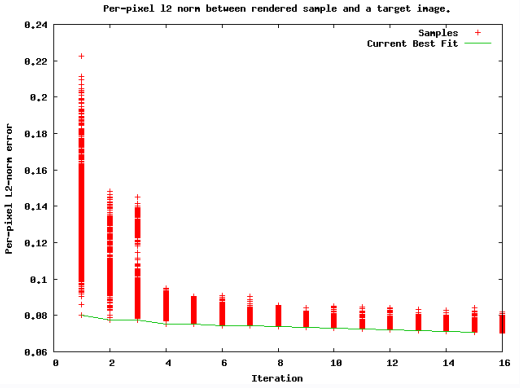
Images of randomly generated models.

Face model and pose generated by the algorithm.

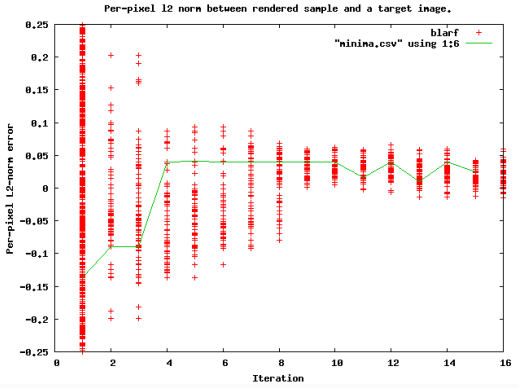
Face fitting examples using synthetically generated targets.

The top row show three examples of faces images generated from the Morphable Model using randomly generated parameters, together with randomly generated pose and position. The bottom row shows the results of applying the GaFF algorithm to the head above.

Exploration



Horizontal position sampled over successive iterations.

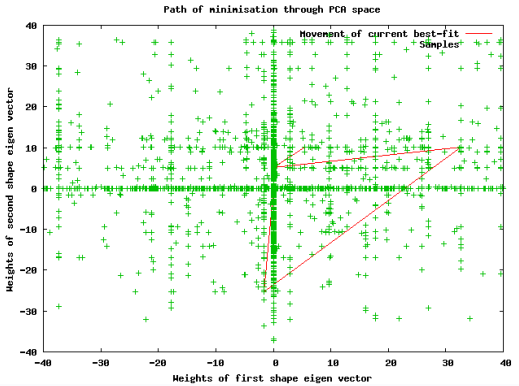


Horizontal scale sampled over successive iterations.

The Genetic Algorithm avoids local-minima by performing a wider (though non-exhaustive) search through the feature space.

We can see this process at work in the above graph. Each point represents a value of the particular parameter (in this case horizontal position). The algorithm searches through a number of separate possible areas of fit before settling on one particular area that it believes contains the global minima. The top-right graph shows this more clearly.

The lower graph illustrates the apparently erratic behaviour of the search. In reality showing the dangers of fitting a low-variance parameter before a high-variance one. In this case pose dominates the search.



Preliminary Results

The Genetic Algorithm as outlined performs well on synthetic images with a black-background. It is clearly capable of fitting faces with a wide variety of shape and poses, all without human intervention. Fitting to synthetic image is a much simple task than attempting to extract three-dimensional shape information from a photograph. However synthetic images have known parameters with which to compare the resulting fit and so may prove vital to analysis.

Further research

- **Fitting to real photographs** is a much harder proposition than the synthetic results shown here.
- **Measures to avoid 'under-fitting'** such as a statistical description of the background of an image.
- **Alternatives to L^2-norm** and edge functions [Rom05]. Investigation of non-continuous and non-differentiable functions. A investigation of alternative cost functions such as the XOR function suggested by Moghaddan et al [MLPM03] is one possible function to investigate.

References

[BV99] BLANZ V., VETTER T.: A morphable model for the synthesis of 3d faces. In *SIGGRAPH '99: Proceedings of the 26th annual conference on Computer graphics and interactive techniques* (New York, NY, USA, 1999), ACM Press/Addison-Wesley Publishing Co., pp. 187–194.

[MLPM03] MOGHADDAM B., LEE J., PFISTER H., MACHIRAJU R.: Model-based 3d face capture with shape-from-silhouettes. In *In IEEE International Workshop on Analysis and Modeling of Faces and Gestures* (2003), p. pages.

[Rom05] ROMDHANI S.: *Face Image Analysis using a Multiple Feature Fitting Strategy*. PhD thesis, University of Basel, 2005.