EigenFIT – the generation of photographic-quality facial composites

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1. Abstract:
The construction of facial composites by assembling individual facial features is common in criminal investigations. Arguably, the best known such method is E-FIT (electronic facial identication technique). However, although humans have excellent facial recognition ability, it is widely recognised that they often have great difficulty recalling facial characteristics in sufficient detail to produce an accurate composite. We outline and demonstrate a new method for the construction of facial composites which offers definite advantages over E-FIT and which also has implications for wider security and biometric applications.

The method proposed combines a randomly generated appearance model (RAM) to produce candidate faces which form the input to an interactive genetic algorithm allowing convergence to the best matching composite.

2. Introduction
All currently used facial composite systems depend upon the ability of a witness to *recall* the subject's features or to recognize them when they are presented in isolation. Many authors working in the late 70s and early 80s in the field of psychology have demonstrated the shortcomings of this approach as a means of identification (Ellis et al 1978, Hines et al 1987, Davies and Christie, 1982, Baddeley 1979)

By contrast, the compact representation of the human face as a truncated expansion over a suitably scaled and normalised set of global principal components (PCA) (first proposed by Sirovich and Kirby 1987) offers an inherently smooth and properly proportioned representation. Whilst many authors have investigated the potential of PCA for *decomposition* and subsequent recognition of a face, its potential for facial *synthesis* has been explored much less.

3. Appearance model
Appearance models differ from standard PCA analysis of faces by producing a vector of coefficients which represent *both the texture and shape* information in the face (Cootes et al 99). In brief, the procedure comprises the following basic steps –

- The faces in the training set are first hand marked at a number of control points to form a shape model and a PCA is carried out on the coordinate ensemble.
- The corresponding texture maps are warped to a standard facial shape and PCA is carried out on these shape-free texture maps.
- The texture and shape components are decorrelated by further applying PCA on the combined model.

Our AM was generated using a sample of 94 high resolution, colour images of white Caucasian females and implemented in Matlab.

The statistics of the coefficients in the AM satisfy a separable, multivariate gaussian distribution. It is therefore a simple matter to randomly generate populations of statistically viable human faces.

4. Interactive Genetic Algorithm
The production of the desired facial composite can be regarded as a search for a unique point in a multi-dimensional face-space each axis of which corresponds to the direction embodied in each principal component. The interactive GA begins with the random generation of the

initial population of faces. Each of these faces is displayed to the user who is prompted to assign a 'fitness" score to each, based on similarity to the target subject. The fitness scores are then used to randomly sample the population and select members for breeding. The breeding stage employs two standard genetic operators – mutation and crossover. However, our algorithm differs from the standard genetic algorithm (Goldberg 89) and is summarised in figure 1 below

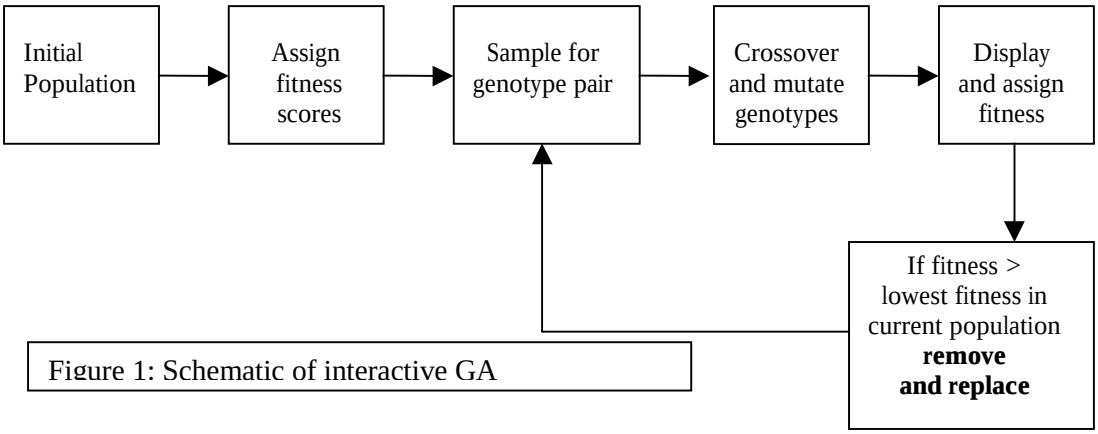

Figure 1: Schematic of interactive GA

5. Summary

The EigenFit system is in its early stages of development but good convergence has been reliably demonstrated in initial trials. An example is shown below in figure 2.

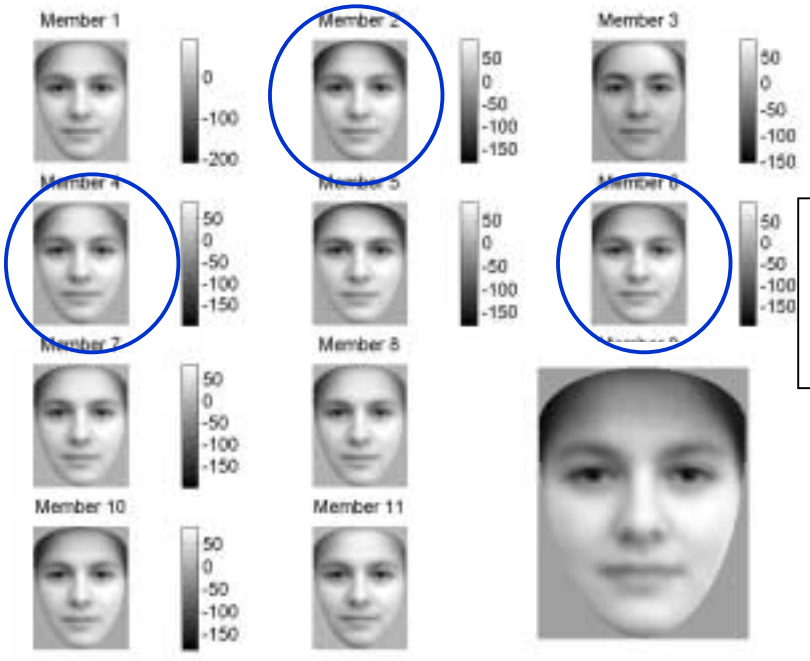

Figure 2: Convergence of the interactive GA on target face

We have demonstrated a facial composite system based on a random appearance model (RAM) coupled to an interactive genetic algorithm which has the capacity to generate life-like, near photographic-quality images. No special skills, training or knowledge are required for its effective use. Further work is planned to generate comprehensive RAMs over a comprehensive sample of gender and ethnic origin and to improve and optimise the convergence properties of the genetic algorithm.

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