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A Comparison of Search Spaces and Evolutionary Operators in Facial Composite Construction





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Motivation

- A person witnesses a crime committed by an unknown perpetrator.
- Investigators wish to create a facial likeness of the unknown perpetrator.
- The conventional approach is to create a feature based facial composite.

http://www.dailymail.co.uk/sciencetech/article-2005960/An-end-traditional-crime-dramas-New-DNA-technology-reveal-committed-crime-HOUR.html

Example of a (conventional) feature based facial composite

http://www.bbc.co.uk/news/uk-wales-mid-wales-11083286

Improving upon the feature based approach

- Recognition of faces is generally holistic; not feature based.
- Facial composite software has been developed which allows a more holistic approach: EFIT-V and EvoFIT.

http://www.essexchronicle.co.uk/James-Attfield-murder-recognise-people/story-20923878-detail/story.html

http://www.psni.police.uk/evofit_carrickfergus_appeal

Face-spaces

- The holistic approach suggests the use of whole face manipulation of composites.
- A multidimensional search space known as a *face-space* is constructed using principal components analysis.
- Faces are represented as points in the face-space.
- The larger the face-space, the more faces that can be rendered.
- The search for a particular face is equivalent to a search for the corresponding point in the face-space.

Use of an interactive evolutionary algorithm

- Searching for the optimum point in a large search space suggests the use of an *interactive evolutionary algorithm* (IEA).
- An IEA is like an evolutionary algorithm except that human evaluation replaces the fitness function.
- Use of human evaluation places a number of constraints on an IEA:
  - Evaluation method.
  - Population size.
  - Number of generations.
- Very little work has been done to compare recombination and mutation operators.

Questions addressed in this work

- Can a human influenced face-space outperform an entirely mathematically based face-space of equal size?
- Is it possible to reduce the size of the face-space and obtain an equally satisfactory result?
- Can the algorithm be improved with an appropriate selection of recombination and mutation operators.

Building the face-spaces

- Based on the procedure used to create the face-spaces in EFIT-V.
- The training set of 27 male and 63 female photographs is processed and its principal components (PCs) are determined.
- PCs are a set of orthogonal axes positioned along the vectors of greatest variance through the data.
- First PC accounts for most variance and so on.
- The PCs can be used to build searchable face-spaces.

Example of a face generated by the face model

Experiment 1: Creating a human influenced face-space

- Aim to find which 12 PCs are perceptually most significant.
- 30 pairs of faces were printed on photographic paper.
- Each pair varied on only one PC.

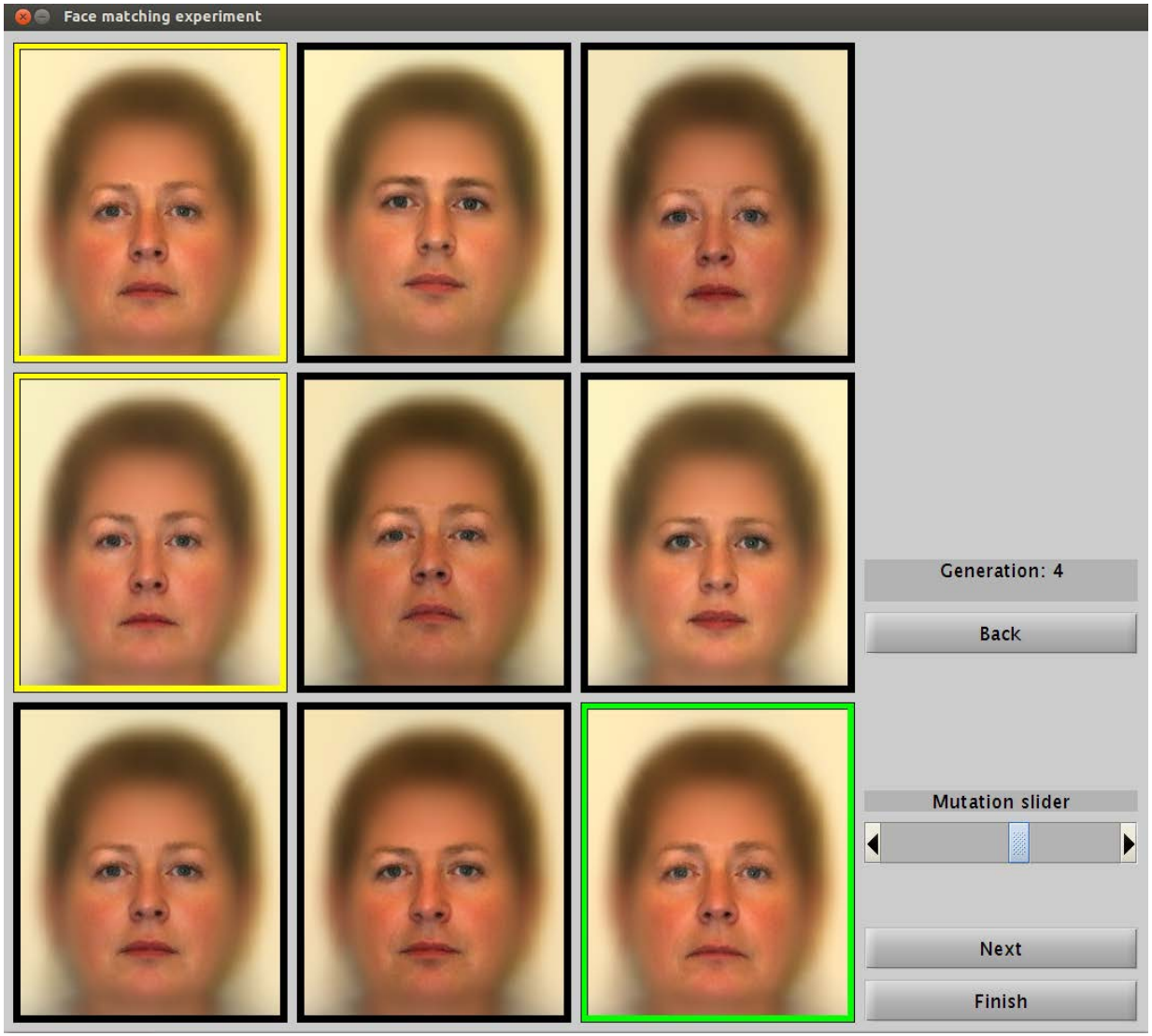
1-st PC

30-th PC

Experiment 1: Creating a human influenced face-space

- Participants ranked the 12 pairs of faces with the greatest within pair dissimilarity.
- The most dissimilar pair scored 12 points and so on.
- Scores were summed over all participants.
- The most significant PCs were 1, 2, 3, 5, 15, 7, 4, 14, 13, 18, 9, and 6.

User interface for experiments 2 and 3



The simple interactive genetic algorithm

- Population size = 9.
- Uses stochastic universal sampling.
- Preferred individual is carried forward to next generation.
- Two parents create one child – parent pool consists of 16 individuals.
- Preferred individual is given 2 slots, other selected individuals are given one each.

Recombination

- Arithmetic crossover

$$c = \frac{(p_1 + p_2)}{2}$$

- Uniform crossover

$$c = p_1 \cdot (\text{Random binary string}) + p_2 \cdot (\text{Bit flip of random binary string})$$

Mutation

- Gaussian replacement

$$p = m \cdot \frac{5}{(\text{Dimensionality of the face space})}$$

$$c_i' \in \sigma_i \cdot N(0,1)$$

- Non-uniform mutation

$$c_i' = c_i + \sigma_i \cdot m \cdot N(0,1)$$

- Face-spaces are bounded such that

$$c_i, c_i' \in [-2.5\sigma_i, 2.5\sigma_i]$$

Experiment 2: Comparing operators

- Two recombination operators and two mutation operators were compared.
- Experiment was done in the human reduced 12-dimensional face-space.
- Target faces were in the face-space.
- Initial population was developed using k-means clustering.

Experiment 2: Comparing operators

- Participants have 10 seconds to memorise the target face.
- The participant creates a composite.
- When done, the participant rates their composite on a scale of 1-10 first without and then with the target present.
- Participants perform the task five times; one practice run and once for each combination of operators.

Experiment 2: Comparing operators

- The measure variables were:
  - Number of generations taken.
  - Time taken.
  - Number of times the back button was used.
  - The without target similarity rating.
  - The with target similarity rating.
- The results were analysed using 2-way ANOVA.
- No statistically significant differences were found between the operators.

Experiment 3: Comparing face-spaces

- Three face-spaces were compared:
  - 30-dimensional.
  - Human reduced 12-dimensional.
  - Mathematically reduced 12-dimensional.
- The target faces were not in the 12-dimensional face-spaces.
- Arithmetic crossover and non-uniform mutation operators used.
- Results were analysed using ANOVA.
- No statistically significant differences were found between the face-spaces.

Conclusions

- Whilst the ordering of the PCs in the reduced face-spaces were different, the face-spaces themselves were similar.
- The choice of recombination and mutation operators had no discernible impact on the efficacy of the IEA.
- The choice of face-space had no discernible impact on the efficacy of the IEA.
- The uncertain nature of creating composites renders any differences in the face-spaces or the operators insignificant.

Thank you for your attention.
Any questions?

Bibliography

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