Data-Driven Enhancement of Facial Attractiveness

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Goal

• Enhance the aesthetic appeal of human faces (facial attractiveness) in frontal photograph while maintaining close similarity with the original
Applications

• A retouching tool for photographer
  – Models on the magazine cover today has been digitally modified by retouching artists
• Construct an avatar or a synthetic actor

Collage blending proposed method
Facial Attractiveness

• A universal notion, transcending the boundaries between different cultures
  – There is a cross-cultural agreement in facial attractiveness rating among rater from different ethnicities, socio-economic classes, ages, gender[1-3]
  – Infant looked longer at the attractive faces regardless of the face’s gender, race, age[4-5]
• The perception of facial attractiveness is data-driven[1-3]

- An facial attractiveness predictor, based on supervised learning techniques.
- Training set
  - 92 frontal portraits of young Caucasian females with neutral expressions
  - Rated by 28 raters (males and females)
- Various regressor were trained based on 40 feature reflected geometry of the face, color of the hair, smoothness of the skin
- The best regressor achieved 0.6 correlation with human rating
Training Sets

• Face image
  – 92 young Caucasian female portraits from [6]
  – 33 young Caucasian male portraits

• Beauty Score
  – Reduce the effect of non-geometric features
    \[ y = y_{orig} - y_{lin} \]
  – \( y_{lin} \): the linear regression based on non-geometric features
System Overview

Original Facial Data
- feature points
- distances vector

Training Set

Beautification engine
- Modified distances vector
- distance embedding

input image → image warp → result image
Facial Feature Extraction

- Extract 84 feature points by BTSM (an improved ASM) [7-8]
  - Point distribution model (Shape Variations)
  - Grey gradient distribution model (Local Texture)
- Delaunay Triangulation
  - 234D distance vector (normalized by the square root of the face area)
System Overview
Support Vector Regression (SVR)

- Similar to support vector machine (SVM) but used for data regression

SVM\[ f(x) = \text{sign}(w^T x + b) \]

SVR\[ f(x) = w^T x + b \]

minimize \( \frac{1}{2} \|w\|^2 \)
subject to \( y_i (w^T \cdot x_i + b) \geq 1 \)

minimize \( \frac{1}{2} \|w\|^2 \)
subject to \( \|y_i - (w^T \cdot x_i + b)\| \leq \varepsilon \)
Support Vector Regression (SVR)

• Define function $f_b : \mathbb{R}^d \rightarrow \mathbb{R}, \ d = 234$
  – Estimate the beauty score from 234 D distance vector

• Using Radial Basis Function kernel to model non-linear behavior

$$x \mapsto \phi(x)$$

$$\phi(x) = (\phi_1(x), \phi_2(x), \ldots)$$

$$K(x_i, x_j) = \phi(x_i)^T \phi(x_j)$$

$$= e^{-\gamma \|x_i - x_j\|^2}$$
Beatification Process

• Given the normalized distance vector \( \mathbf{v} \) generate a nearby vector \( \mathbf{v}' \) such that
  \[ f_b(\mathbf{v}') > f_b(\mathbf{v}) \]

• Two methods:
  – KNN-based beautification
  – SVR-based beautification
KNN-Based Beautification

- Give a weight value to each faces in the training set: \( w_i = \frac{b_i}{\|v - v_i\|} \)
  - \( v \): input distance vector
  - \( b_i, v_i \): the \( i^{th} \) beauty score and distance vector in the train set

- Sort \( \{v_i\} \) by \( w_i \), such that \( w_i \geq w_{i+1} \)

- The beautified distance vector \( v' \) is the weighted sum of the first \( K \) \( \{v_i\} \)s

\[
    v' = \frac{\sum_{i=1}^{K} w_i v_i}{\sum_{i=1}^{K} w_i}
\]
Beauty Score v.s. $K$
SVR-Based Beautification

- Directly use $f_b$ to seek beautified distance vector $v'$
  
  $v' = \arg\min_u E(u), \text{ where } E(u) = -f_b(u)$

- Use standard no-derivatives Direction Set Method to perform minimization

- Feature dimensions are reduced to 35D by PCA
SVR-Based Beautification

• **Drawbacks**
  – Sometimes yielding distance vectors that correspond to **invalid** human face distances

• **Adding log-likelihood term** \((LP)\)
  \[
  E(u) = -(1 - \alpha)f_b(u) - \alpha LP(u)
  \]

• **\(LP\) is approximated by modeling face space as a multivariate Gaussian distribution**
System Overview

Original Facial Data
- Feature points
- Distances vector

Training Set

Beautification engine

Modified distances vector

Distance embedding

Input image → Image warp → Result image
Distance Embedding and Warping

- To convert modified distances $v'$ to new facial landmark

$$E(q_1, \ldots, q_N) = \sum_{e_{ij}} \alpha_{ij} \left( \|q_i - q_j\|^2 - d_{ij}^2 \right)^2$$

- $q_i$: target landmark position
- $e_{ij}$: facial mesh connectivity
- $\alpha_{ij}$: 1 for edges between diff facial feature
- 10 for edges between same facial feature
- $d_{ij}$: target distance, the entry in $v'$ that correspond to edge $e_{ij}$

- Minimize $E(\ldots)$ by LM algorithm
Distance Embedding and Warping

- Post-process by enforcing similarity transform on the features points of eyes

\[ S = \begin{pmatrix} a & b & t_x \\ -b & a & t_y \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} s \cos \theta & -s \sin \theta & t_x \\ s \sin \theta & s \cos \theta & t_y \\ 0 & 0 & 1 \end{pmatrix} \]

- Minimize \( \sum \|Sp_i - q_i\|^2 \)

- \( Sp_i \) replace \( q_i \) to preserve the shape of original eyes

- Warping image from \( p_i \) to \( q_i \) using MFFD
Result and Subjective Tests
Results (Training Set)

<table>
<thead>
<tr>
<th>Original portrait</th>
<th>3.37 (0.49)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warped to mean</td>
<td>3.75 (0.49)</td>
</tr>
<tr>
<td>KNN-beautified (best)</td>
<td>4.14 (0.51)</td>
</tr>
<tr>
<td>SVR-beautified</td>
<td>4.51 (0.49)</td>
</tr>
</tbody>
</table>
Results (not in Training Set)

From AR face database

Other sources
Results (Partial Beautify)

(a) Original
(b) full beautified
(c) partial beautified

(d) Only eyes
(e) Mouth excluded
Results (Degree of Beautification)

0% beautified

50% beautified

100% beautified
Results (Fail for Child)
Results (Application Screen Shot)
Subjective Test (Original v.s. Beautified)

- 92 faces from AR database (45 male, 47 female)
- 68 raters (aged 25~40)
- Results
  - Female portrait:
    - beautified versions are preferred by most raters
    - half of cases, beautified versions preferred by more than 80% raters
  - Male portrait:
    - 69% beautified version are preferred
  - Statistically Significant (P-value=0.006)
Subjective Test (SVR v.s. mean)

- The same 47 female faces
- 21 raters

Results
- 17 (out of 21) raters preferred SVR result over the majority of the faces (P-value 0.0015)
- 36 (out of 47) SVR-based beautified faces were preferred by most raters (P-value 9.8x10^{-5})
Conclusion and Future Works

• Conclusion
  – A digital face beautification method based on optimization of a beauty function modeled by support vector regressor is presented

• Future Works
  – Handle general views and other expressions
  – Adding other non-geometric attribute: color and texture of hair and skin
  – Data-driven enhancement of the aesthetics of other shape classes
References


Thank You!!