Modelling Appearance

Cootes, Edwards, Taylor
University of Manchester
Lessons learned

- ASM is relatively fast
- ASM too simplistic; not robust when new images are introduced
- May not converge to a good solution
- Key insight: ASM does not incorporate all gray-level information in parameters
Combined Appearance Models

- Combine shape and gray-level variation in single statistical appearance model
- Goals:
  - Model has better representational power
  - Model inherits appearance models benefits
  - Model has comparable performance
How to generate a AAM

- Label training set with landmark points representing positions of key features
- Represent these landmarks as a vector $x$
- Perform PCA on these landmark vectors
Appearance Models

- Statistical models of shape *and* texture

- Generative models
  - general
  - specific
  - compact (~100 params)
Building an Appearance Model

- Labelled training images
  - landmarks represent correspondences
Building an Appearance Model

- For each example

Shape: \( x = (x_1, y_1, \ldots, x_n, y_n)^T \)

Warp to mean shape

Texture: \( g \)

Raster Scan
Building an Appearance Model

- Principal component analysis
  - shape model: \( \mathbf{x} = \overline{\mathbf{x}} + \mathbf{P}_s \mathbf{b}_s \)
  - texture model: \( \mathbf{g} = \overline{\mathbf{g}} + \mathbf{P}_g \mathbf{b}_g \)

- Columns of \( \mathbf{P}_r \) form shape and texture bases
- Parameters \( \mathbf{b}_r \) control modes of variation
Shape and Texture Modes

Shape variation (texture fixed)

Texture variation (shape fixed)
Combined Appearance Model

- Shape and texture may be correlated

\[ \text{PCA of } \begin{pmatrix} b_s \\ b_g \end{pmatrix} \rightarrow \begin{pmatrix} x \\ g \end{pmatrix} = \begin{pmatrix} \bar{x} \\ \bar{g} \end{pmatrix} + \begin{pmatrix} Q_x \\ Q_g \end{pmatrix} c \]

Varying appearance vector \( c \)
Colour Appearance Model

\[ c_1 \quad c_2 \quad c_3 \]
AAM Properties

- Combines shape and gray-level variations in one model
  - No need for separate models
- Compared to separate models, in general, needs fewer parameters
- Uses all available information
AAM Properties (cont.)

- Inherits appearance model benefits
  - Able to represent any face within bounds of the training set
  - Robust interpretation
- Model parameters characterize facial features
AAM Properties (cont.)

- Obtain parameters for inter and intra class variation (identity and residual parameters) – “explains” face
AAM Properties (cont.)

- Useful for tracking and identification

- Note: shape and gray-level variations are correlated
AAM Search

- Features
- Identity
- Expression
- Pose
- Lighting

Model Parameters
Practical Applications
Face Tracking

Original                             Tracking
Car Model

Main Mode of Variation

Original

Search
MR Brain Slice

Combined Mode 1

Combined Mode 2
MR Brain Slice - Search
MR Knee Cartilage
Summary

- Generic approach - *analysis by synthesis*
- Robust image interpretation
- Labelled structure
  - segmentation, measurement
- Recognition
  - parametric description
- Practical applications
Constrained AAMs

- Model results rely on starting approximation
- Want a method to improve influence from starting approximation
- Incorporate priors/user input on unseen image
  - MAP formulation
Constrained AAMs

Assume:

- Gray-scale errors are uniform gaussian with variance $\sigma^2_r$
- Model parameters are gaussian with diagonal covariance $S^2_p$
- Prior estimates of some of the positions in the image along with covariances
Constrained AAMs (cont.)

- We get update equation:

\[ A_1 \delta p = -a_1 \]

where:

\[
A_1 = \left( \sigma_r^{-2} \frac{\partial r}{\partial p}^T \frac{\partial r}{\partial p} + S_p^{-1} + \frac{\partial d}{\partial p}^T S_X^{-1} \frac{\partial d}{\partial p} \right)
\]

\[
a_1 = \left( \sigma_r^{-2} \frac{\partial r}{\partial p}^T r(p) + S_p^{-1} p + \frac{\partial d}{\partial p}^T S_X^{-1} d \right)
\]
Constrained AAMs

- Comparison of constrained and unconstrained AAM search
Conclusions

- Combined Appearance Models provide an effective means to separate identity and intra-class variation
  - Can be used for tracking and face classification
- Active Appearance Models enables us to effectively and efficiently update the model parameters
Conclusions (cont.)

- Approach dependent on starting approximation
- Cannot directly handle cases well outside of the training set (e.g. occlusions, extremely deformable objects)
End