Active Appearance Models

Advanced Image Processing (CS7960)

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Outline

• Review of Active Shape Model (ASM)
• Extension to texture models
• Combined appearance models
• Active Appearance Model (AAM)
• Examples
• Conclusion
ASM

• A set of labeled training images
• Mutual alignment
• Statistical analysis (PCA)
• ASM:

\[ \mathbf{x} = \overline{\mathbf{x}} + \mathbf{P}_S \mathbf{b}_S \]
Drawbacks of ASM

• It is very sensitive to initialization.
• Only uses shape constraints.
• Does not use all the grey-level information available.
• May not converge to good solution.
Texture Models

- Warp each shape to the mean shape.
- Warping can be done Delaunay triangulation.
Texture Models (cont’d)

• Sample the grey-level information over the region covered by the mean shape, $g_{im}$.

• Normalize $g_{im}$.

$$g = \frac{g_{im} - \beta 1}{\alpha} \quad \alpha = g_{im} \cdot \bar{g} \quad \beta = \frac{g_{im} \cdot 1}{n}$$
Texture Models (cont’d)

- Apply PCA to model the statistical variation:

\[ g = \bar{g} + P_g b_g \]
Combined Model

• The shape and texture parameter vectors are combined:

\[
b = \begin{bmatrix} W_s b_s \\ b_g \end{bmatrix} = \begin{bmatrix} W_s P_s^T (x - \bar{x}) \\ P_g^T (g - \bar{g}) \end{bmatrix}
\]
Choice of $W_s$

- Systematically displace $b_s$ on each training image.
- Sample the image given the displace shape.
- Compute RMS change in $g$ per unit change in $b_s$. 
PCA on Combined Model

• Apply PCA on the combined parameter vector:

\[ b = Qc \]

• The final appearance model is:

\[
\begin{align*}
x &= x + P_s W_s Q_s c \\
g &= g + P_g Q_g c \\
Q &= \begin{bmatrix} Q_s \\ Q_g \end{bmatrix}
\end{align*}
\]
Error Definition

• The search is treated as an optimization problem where the error is to minimized:

\[ \delta I = I_i - I_m \]

\[ \Delta = \min_c \left| \delta I \right|^2 \]
AAM

• The idea is to learn relationship between $\delta I$ and parameter adjustments by using a-priori knowledge of how these parameters change from the training set.

• Multivariate linear regression.
AAM (cont’d)

- Let \( t \) and \( u \) be the shape and texture pose parameters in an image:

\[
X = T_t(x)
\]

\[
g_{im} = T_u(g)
\]

\[
t = \begin{bmatrix} s_x, s_y, t_x, t_y \end{bmatrix}^T
\]

\[
u = \begin{bmatrix} \alpha - 1, \beta \end{bmatrix}^T
\]
AAM (cont’d)

• Define:
  \[ p^T = [c^T | t^T | u^T] \]

• Let
  \[ r(p) = g_i - g_m \]
  \[ r(p + \delta p) = r(p) + \frac{\partial r}{\partial p} \delta p \]
AAM (cont’d)

• Suppose the current residual is \( r(p) \), we wish to choose \( \delta p \) so as to minimize \( \left| r(p + \delta p) \right|^2 \)

\[
\delta p = -\left( \frac{\partial r}{\partial p} \frac{\partial r}{\partial p} \right)^{-1} \frac{\partial r}{\partial p}^{T} r(p)
\]
Linear Regression

- \( \frac{\partial r}{\partial p} \) is estimated by systematically displacing each parameter from their known optimal value and computing an average over the training set.

- Typical displacement is up to 0.5 standard deviations of each parameter.
Iterative Model Refinement

- Evaluate error vector: \( \mathbf{r}_0 = \mathbf{g}_i - \mathbf{g}_m \)
- Evaluate the current error: \( E_0 = |\mathbf{r}_0|^2 \)
- Compute the displacement: \( \delta \mathbf{p} = -\mathbf{R} \mathbf{r}_0 \)
- Set \( k = 1 \), let \( \mathbf{p}_1 = \mathbf{p}_0 - k \delta \mathbf{p} \)
- Calculate new error vector, \( \mathbf{r}_1 \)
- If \( |\mathbf{r}_1|^2 < E_0 \), then accept new estimate \( \mathbf{p}_1 \)
- Otherwise try \( k = 1.5, k = 0.5, k = 0.25 \) e.t.c
Example (Face)
Questions?