Active Appearance Models

• Suppose we have a statistical appearance model
  – Trained from sets of examples
• How do we use it to interpret new images?
• Use an “Active Appearance Model”
• Iterative method of matching model to image

Interpreting Images (1)

Place model in image
Measure Difference
Update Model
Iterate

Quality of Match

• Residual difference: \( r(p) = I_n(p) - I_m(p) \)
• \( p \) : all parameters, eg \( p = (c, X, Y, s, \theta) \)
• Ideally find and optimise \( p(p) \)

Bayes rule: \( p(p | r) = \frac{p(r | p)p(p)}{p(r)} \)

• Cannot usually know \( p(r) \)

Quality of Match

• Usually attempt to maximise
  \( p(r | p)p(p) \)
• This is equivalent to maximising
  \( \log p(r(p) | p) + \log p(p) \)
• Which is equivalent to minimising
  \( E(p) = -\log p(r(p)) - \log p(p) \)

Quality of Match

• Assuming independent gaussian noise:
  \[ p(r(p)) \propto \exp\left(-\frac{r(p)^T r(p)}{2\sigma_r^2}\right) \]
  \[ \log p(r(p)) \propto \frac{-r(p)^T r(p)}{2\sigma_r^2} \text{ + const} \]
  \[ E(p) \propto \frac{|r(p)|^2}{2\sigma_r^2} - \log p(p) + \text{const} \]

Quality of Match

• If we assume all parameters equally likely (within certain limits)
  \[ p(p) = \text{const} \]
  \[ E(p) = \frac{|r(p)|^2}{2\sigma_r^2} + \text{const} \]
• Thus we need to find the parameters which minimise the sum of squares of residuals,
  \[ E(p) = |r(p)|^2 \]
Quality of Match

• If we assume parameters have a gaussian distribution,
  \[ p(p) \propto \exp(-0.5p^T S^{-1} p) \]
• We must then minimise
  \[ E(p) = \frac{|r(p)|^2}{2\sigma_t^2} + 0.5p^T S^{-1} p \]

Optimising the Match

• We must find \( p \) to minimise \( E(p) \)
• \( p \) may have many (100’s) of dimensions
  – Can put into a multi-dimensional optimiser
  – Likely to be rather slow
• We can use some cunning approximations to find good solution rapidly

Key Insight

• Image error related to error in \( p \)

Learning the Relationship

• For each of a training set
  – find best fit given landmarks, \( p \)
  – randomly perturb \( p \) by \( \delta p \) and measure
  \[ r(p + \delta p) = I_n(p) - I_n(p + \delta p) \] (in model frame)
• Multivariate regression to learn \( R \) in
  \[ \delta p = Rr(p + \delta p) \]

More Analytic Approach

\[ r(p + \delta p) = r(p) + \frac{\partial r}{\partial p} \delta p \]
To minimize \( E(p + \delta p) \),
\[ \delta p = -Rr(p) \]
\[ R = \left( \frac{\partial r}{\partial p} \frac{\partial r}{\partial p} \right)^{-1} \frac{\partial r}{\partial p} \]

How Good are the Predictions?

• Predicted \( \delta x \) vs. actual \( \delta x \) over test set
Multi-Resolution Predictions

• Predicted $\delta x$ vs. actual $\delta x$ over test set

AAM Algorithm

• Initial estimate $I_m(p)$
• Start at coarse resolution
• At each resolution
  – Measure residual error, $r(p)$
  – predict correction $\delta p = Rr$
  – $p \Rightarrow p \cdot \delta p$
  – repeat to convergence

Face Search Example

Sub-cortical Structures

Sub-cortical Structures

Brain search
**Search Accuracy (Brain images)**

- Leave-1-out search experiments
  - For each image in training set:
    - Train model on all current image,
    - test on that image
  - average results over all images

**Examples of Failure**

- Poor initialisation can lead to failure
- Only samples current region
  - may not cover full extent of target

**MR Knee Cartilage**

**Higher Dimensional Images**

- 3D
- 2D+time
- 3D+time
- ASM relatively straightforward
- AAM – problems with size of models

**Problems**

- Automatic Model Building
  - Require correspondences across a set
  - Hard to achieve reliably
  - Human interaction can impart expert knowledge

**Correspondence Important**

Manual Annotation   |   Equally spaced points
Problems

- Reliable measure of quality of fit
  - Necessary for good matching
  - Essential for detection (e.g., is object present at all?)
  - RMS of residual too sensitive to positional errors
- Model initialisation
  - Getting good initial estimate can be hard

Problems

- Failures to match at edges of model
  - Perhaps need some model of whole image
  - Multiple initialisations can help