Statistical Models of Appearance for Image Interpretation

T.F Cootes & C.J. Taylor

Harsh Nanda

30th September, 2003

Problem Overview

- Image Interpretation
  - Prior knowledge
  - Structure Recovery
  - Labeling
- Model Based Approach
  - Describe and label expected structure
  - Interpretation ≡ Matching

Example

Initial | After 2 iterations | After 6 iterations | After 18 iterations

Modeling

- Model Characteristics
  - What? Shape or Appearance
    - Active Shape Model
    - Active Appearance Model
  - Deformable – General & Specific
- Method
  - Learn variation from annotated image set

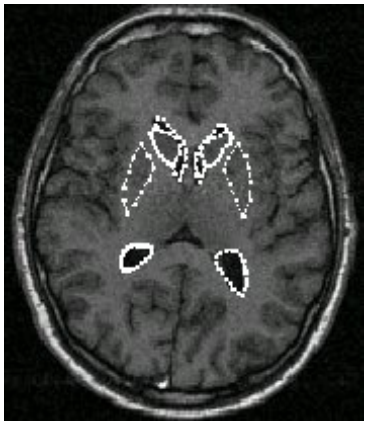
Modeling

- Training Set
  - Annotated Images: Key landmarks
- PCA
  - Shape $\bar{x}$

$$x = \bar{x} + P_s b_s$$

  - Appearance $\bar{g}$

$$g = \bar{g} + P_g b_g$$



Modeling

- Possible correlation b/w shape and appearance
  - PCA on b_s & b_g

$$\begin{pmatrix} \mathbf{W}_s \mathbf{b}_s \\ \mathbf{b}_g \end{pmatrix} = \mathbf{b} = \begin{pmatrix} \mathbf{Q}_s \\ \mathbf{Q}_g \end{pmatrix} \mathbf{c} = \mathbf{Q}\mathbf{c}$$

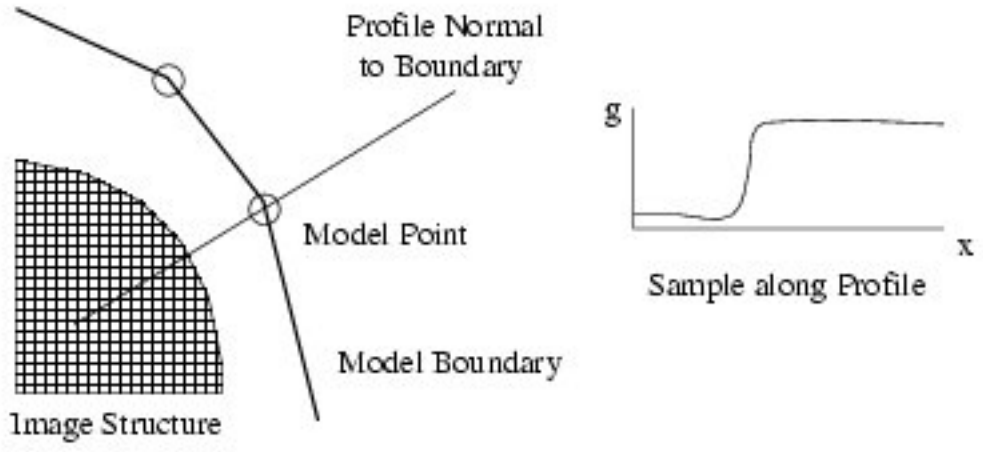
$$\mathbf{x} = \bar{\mathbf{x}} + \mathbf{P}_s \mathbf{W}_s^{-1} \mathbf{Q}_s \mathbf{c} \quad , \quad \mathbf{g} = \bar{\mathbf{g}} + \mathbf{P}_g \mathbf{Q}_g \mathbf{c}$$

- Generating shape & texture in image
  - $X = S_t(x)$
  - $g_{im} = T_u(g)$

Active Shape Model

- Rough starting approximation of *(b,t)*
- Iterate
  - Create an instance of X
  - Examine region **around** X_i
  - Update X_i by replacing by best match X_i'
  - Update *(b,t)* to best fit new X
  - Repeat until convergence

Active Shape Model

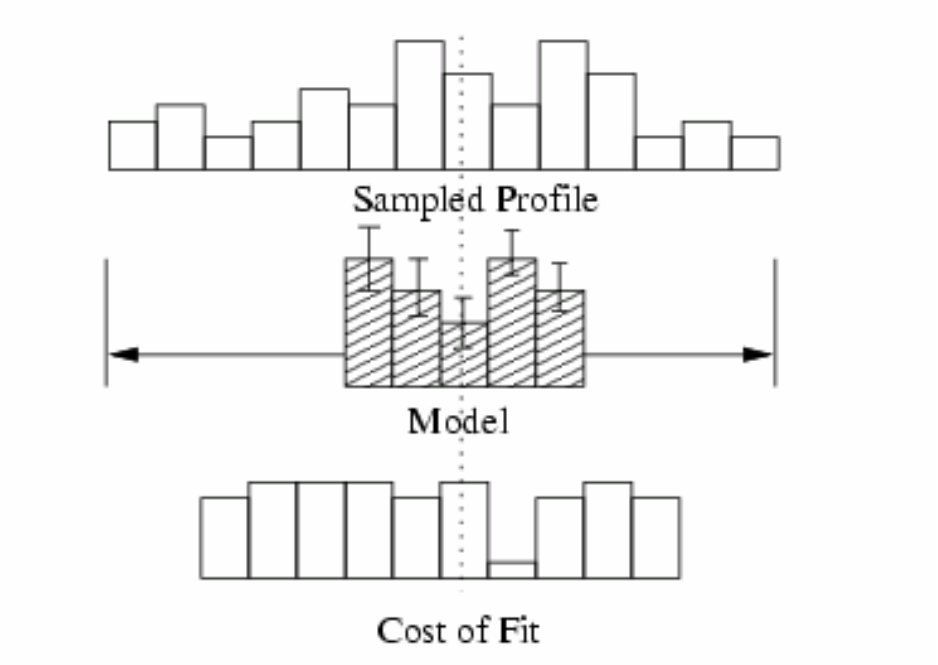


Modelling Local Structure

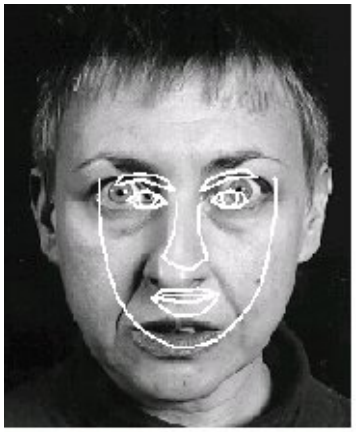
- Sample along a profile *k* pixels on each side to get 2k+1 samples, g_i
- Normalize g_i
- Assume multivariate gaussian distribution, estimate $\bar{g}$ & S_g
- Quality of fit of a new sample g_s

$$f(\mathbf{g}_s) = (\mathbf{g}_s - \hat{\mathbf{g}})^T \mathbf{S}_g^{-1} (\mathbf{g}_s - \hat{\mathbf{g}})$$

Modelling Local Structure



ASM: Example



Initial

After 2 iterations

After 6 iterations

After 18 iterations

Initial

After 2 iterations

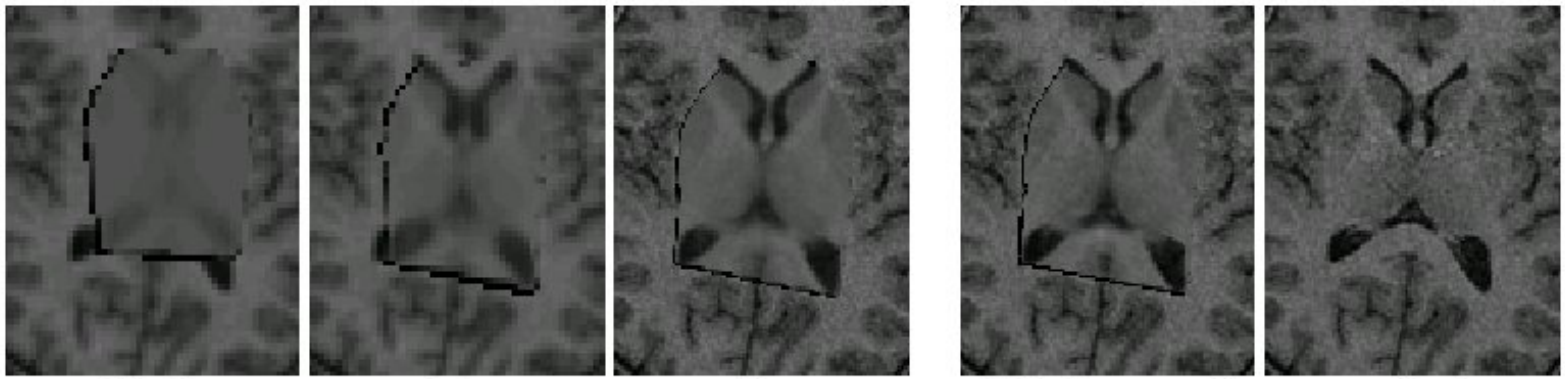
After 20 Iterations

Active Appearance Models

- Rough starting approximation of *(c,t,u)*
- Iterate
  - Create an instance of *X*
  - Sample pixels in this region, g_{im}
  - $g_s = T_u^{-1}(g_{im})$
  - $g_m = g^- + P_g Q_g c$
  - $r(p) = g_s - g_m$ $\qquad\qquad$ $(p' = (c'|t'|u'))$
  - $p = p + k*r(p)$

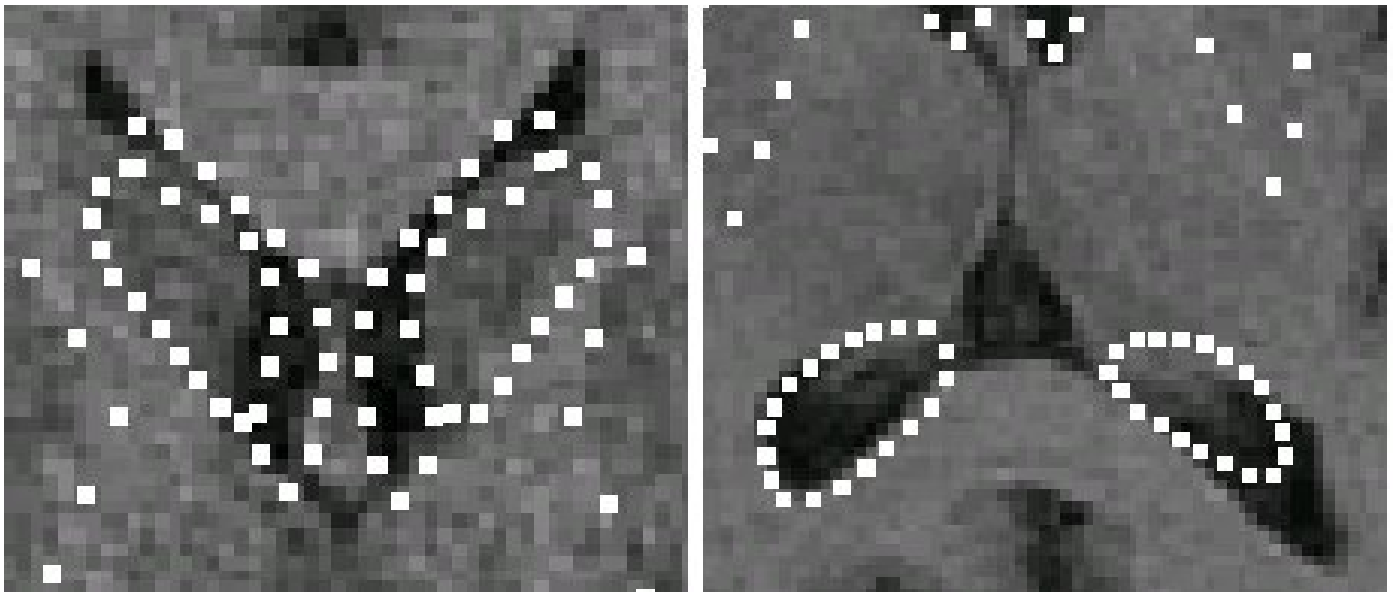
AAM: Example

- Central structure of brain slice
- 10000 pixels & 30 **c** parameters



AAM: Limitations

- AAM usually close to optimal but not exact



AAM: Improvements

- Model whole visible structure
- Explicit searching outside current patch e.g. along normal as ASM
- Multiple starting points
- Combine AAM & ASM: Weighted average of independent runs

Multi-Resolution Framework

- Methodology
  - Generate image pyramid by sub-sampling
  - Search subject in coarse image
  - Refine location at higher resolution
- Advantages
  - Efficiency
  - Robustness

Comparison: ASM v/s AAM

- ASMs look around, AAMs look inside
  - ASM larger capture range, fast
  - AAM more stable
- ASM need more model points, AAM, convincing model with relatively small number of landmarks
- ASM, more accurate feature point location, AAM, better texture match