Lecture 15
Active Shape Models

Methods in Medical Image Analysis - Spring 2024
16-725 (CMU RI) : BioE 2630 (Pitt)
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Active Shape Models (ASM) & Active Appearance Models (AAM)

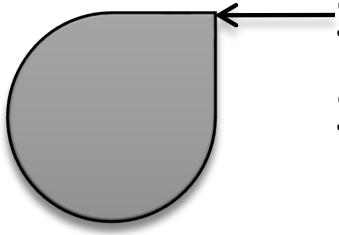
- We'll cover mostly the original active shape models.
- TF Cootes, CJ Taylor, DH Cooper, J Graham, *Computer Vision and Image Understanding*, Vol 61, No 1, January, pp. 38-59, 1995
- Conceptually an extension of Eigenfaces
- ITK Software Guide book 2, section 4.3.7

ASM & AAM Patent Warning!

- Active shape models and active appearance models are not completely free of patents!
- I am not a lawyer. You alone are responsible for checking and verifying that you comply with patent law.
- It has been claimed that “there is no patent on the core AAM algorithms” (and so I presume not on the core ASM algorithms either), but that there are “patents concerning related work on separating different types of variation (e.g; expression vs identity for faces) and on the use of the AAM with certain non-linear features rather than the raw intensity models”
  http://www.itk.org/pipermail/insight-developers/2004-September/005902.html

Why ASM?

- Back in 1995, active contour algorithms had relatively poor shape constraints
  - You could limit overall curvature, but…
  - There was no easy way to specify that one part of a shape should look much different than another part of the same object
  - Example: No easy way to specify a shape should like this:



Sharp curvature here, but…

Shallow curvature everywhere else

ASM's Solution

- Represent shapes as a sequence of connected landmarks
  - Place landmarks at unique boundary locations
  - E.g., salient points on the boundary curves
  - Easier to handle than the an entire border, and more descriptive
- Build a statistical shape model: where do/should the landmarks appear for a given object?
  - What does the "average" shape look like?
  - What kinds of variation are normal? (Uses PCA)
  - Does a new shape look reasonably similar to our training data?

ASM Approach (Sumarized)

- Align all shapes (shift their landmarks) with the average (mean) shape
  - Typically pose & scale registration
- Do PCA on the distribution of landmark locations
  - Each shape is a set of landmarks
  - Dimensionality = #Landmarks * #SpatialDimensions = big!
  - Each eigenvector is itself a shape
  - Rescaling primary eigenvectors describes almost all expected shape variations
  - Eigenvalues are the variance explained by each eigenvector (assuming a Gaussian distribution)

Results & More Recent work

- ASMs were a major leap forward!
  - Gracefully segment with noise, occlusion, missing boundaries, etc.
- ASM difficulties:
  - Assumes independence between landmark locations
  - Amorphic shapes (e.g., amoeba)
  - Initialization still matters
  - Pathology→giant outlier→shape won't fit
- After 1995:
  - AAM: Model shape + pixel values
  - Automated training methods
  - *Incorporated into level set framework*

ITK ASM Levelsets

- Build training data:
  - *Accurately* segment your training images
  - Apply itk::SignedDanielssonDistanceMapImageFilter to each
  - Write each processed segmentation to a separate file on disk
- Train your model:
  - itkImagePCAShapeModelEstimator
  - http://www.itk.org/Doxygen/html/classitk_1_1ImagePCAShapeModelEstimator.html
  - http://www.itk.org/Wiki/ITK/Examples/Segmentation/EstimatePCAModel
- Segment your images:
  - itkGeodesicActiveContourShapePriorLevelSetImageFilter
  - http://www.itk.org/Doxygen/html/classitk_1_1GeodesicActiveContourShapePriorLevelSetImageFilter.html
  - ITK Software Guide section 9.3.7 & associated example code
  - Has standard geodesic parameters plus a new one: SetShapePriorScaling()

ITK ASM Levelsets

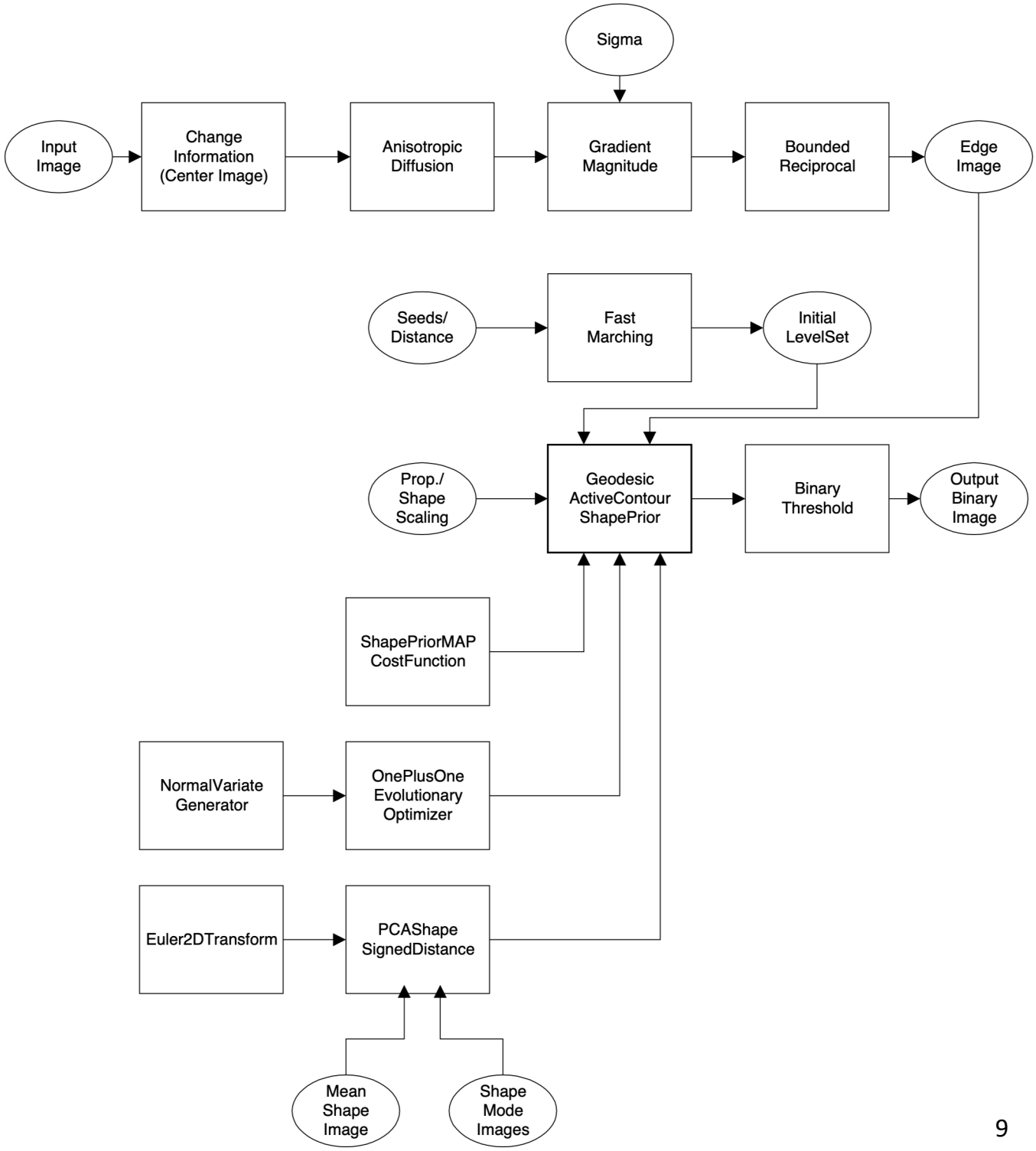



Figure 9.31 from the ITK Software Guide v 2.4, by Luis Ibáñez, et al.