Segmenting & Tracking Ionospheric Enhancements

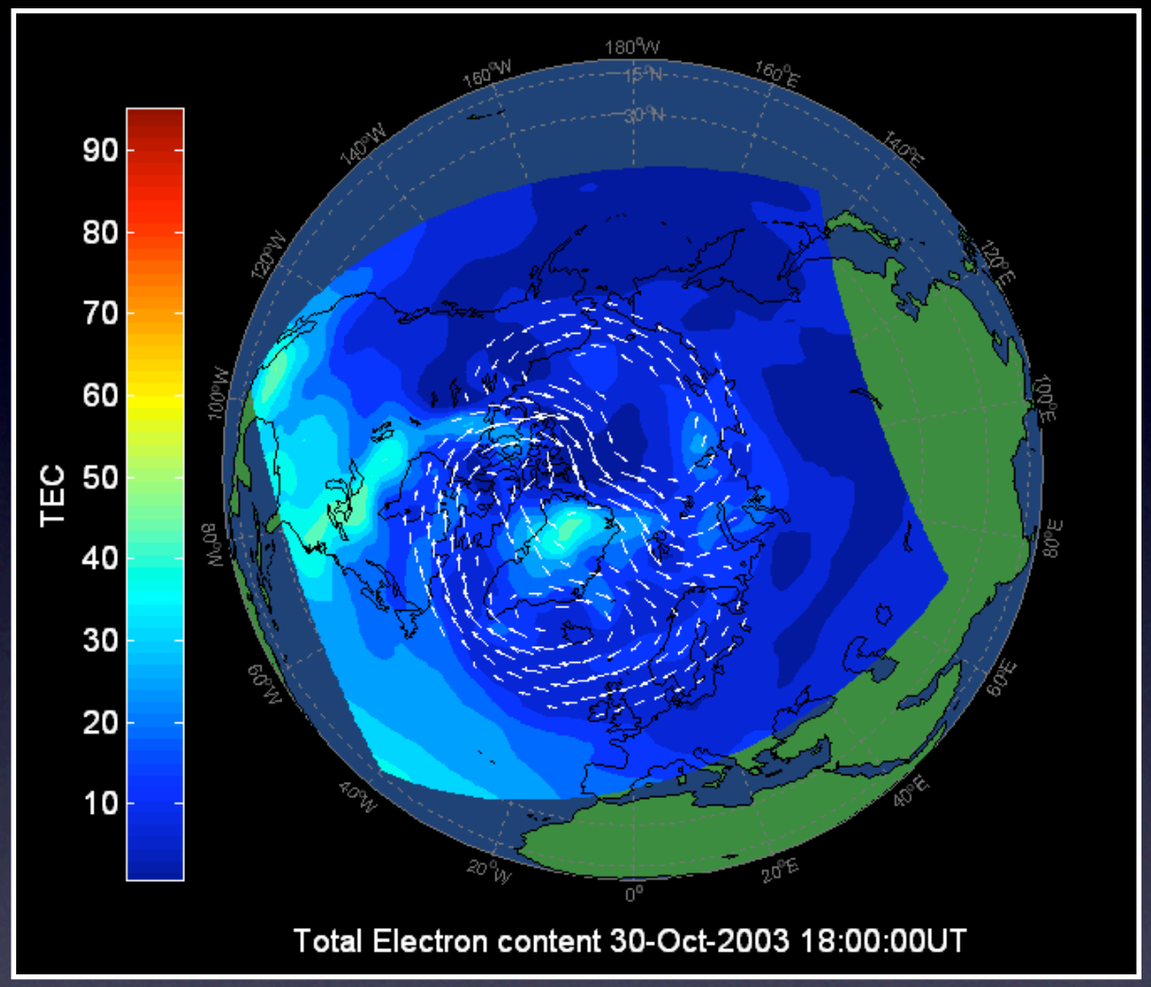
Matt Foster

MTRC Lunch Seminar

Aims

- Geomagnetic storms cause ionospheric enhancements (blobs)
- We want to track these blobs as they cross the northern polar region
- There isn't much information
- 1 pixel = 400 km^2

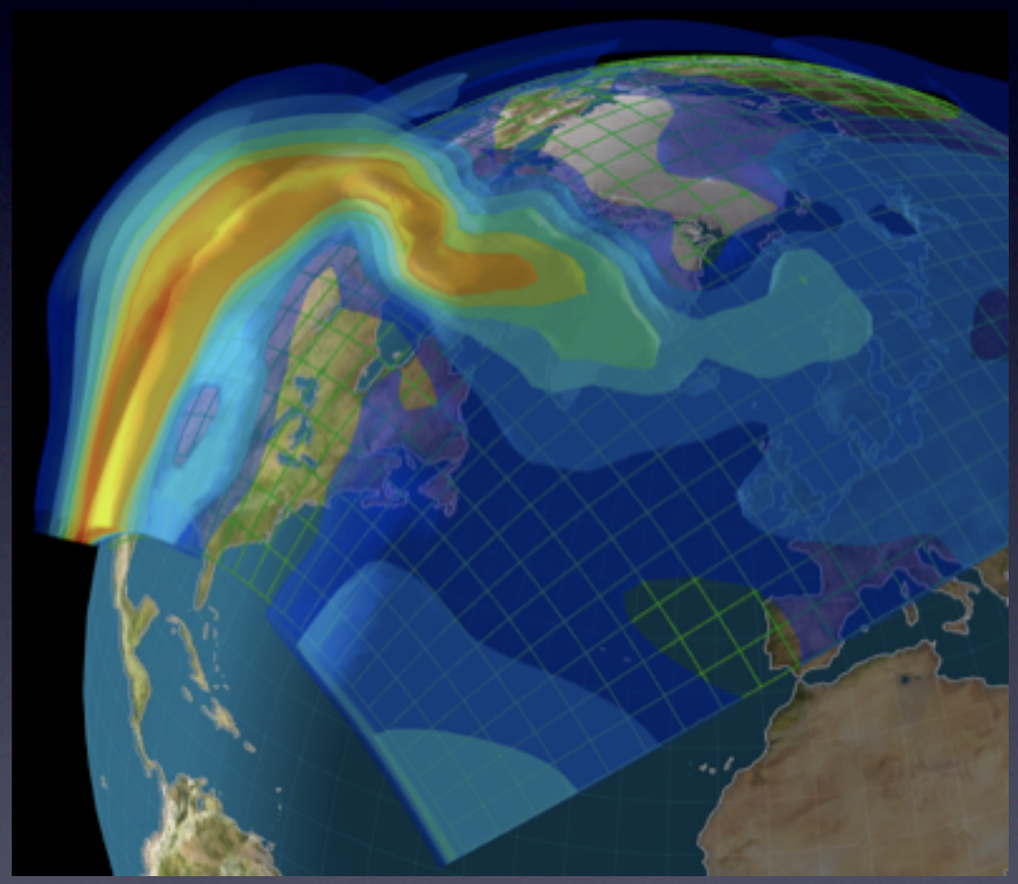
http://www.flickr.com/photos/orvaratli



Modelled Behaviour

Data

- Raw outputs from MIDAS
- 100° x 100° grid
- 4° resolution
- 25 x 25 pixels
- 5 minutes between frames



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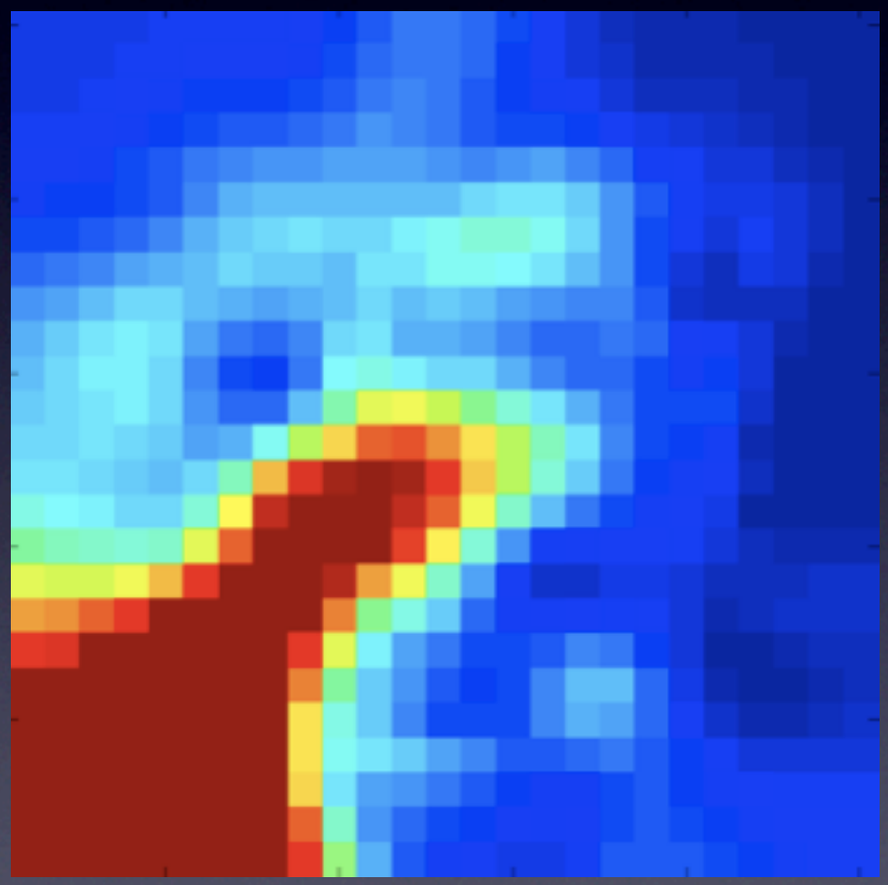
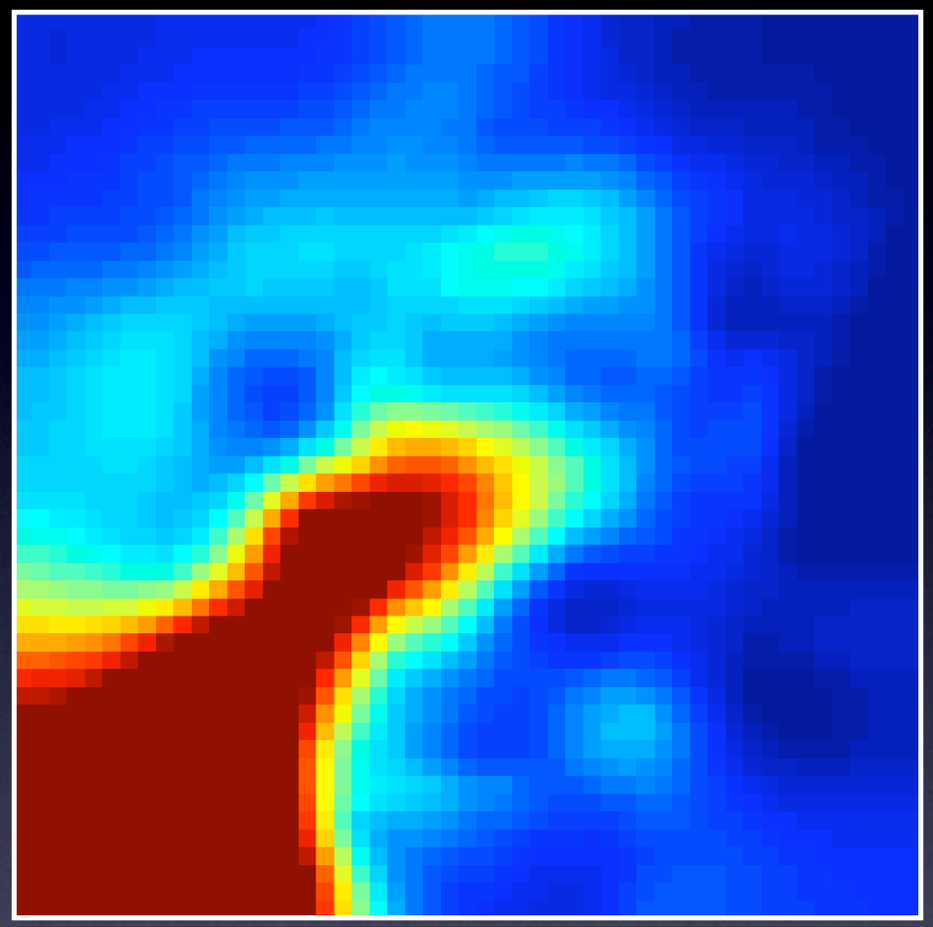
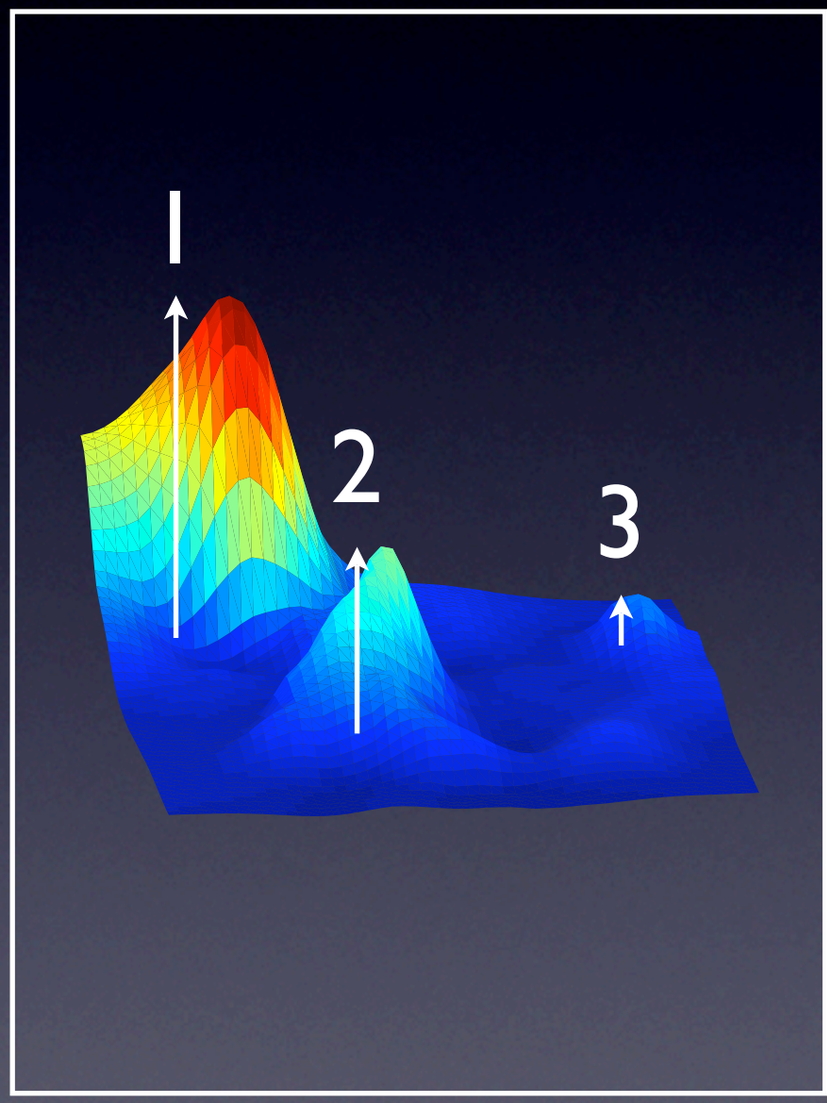




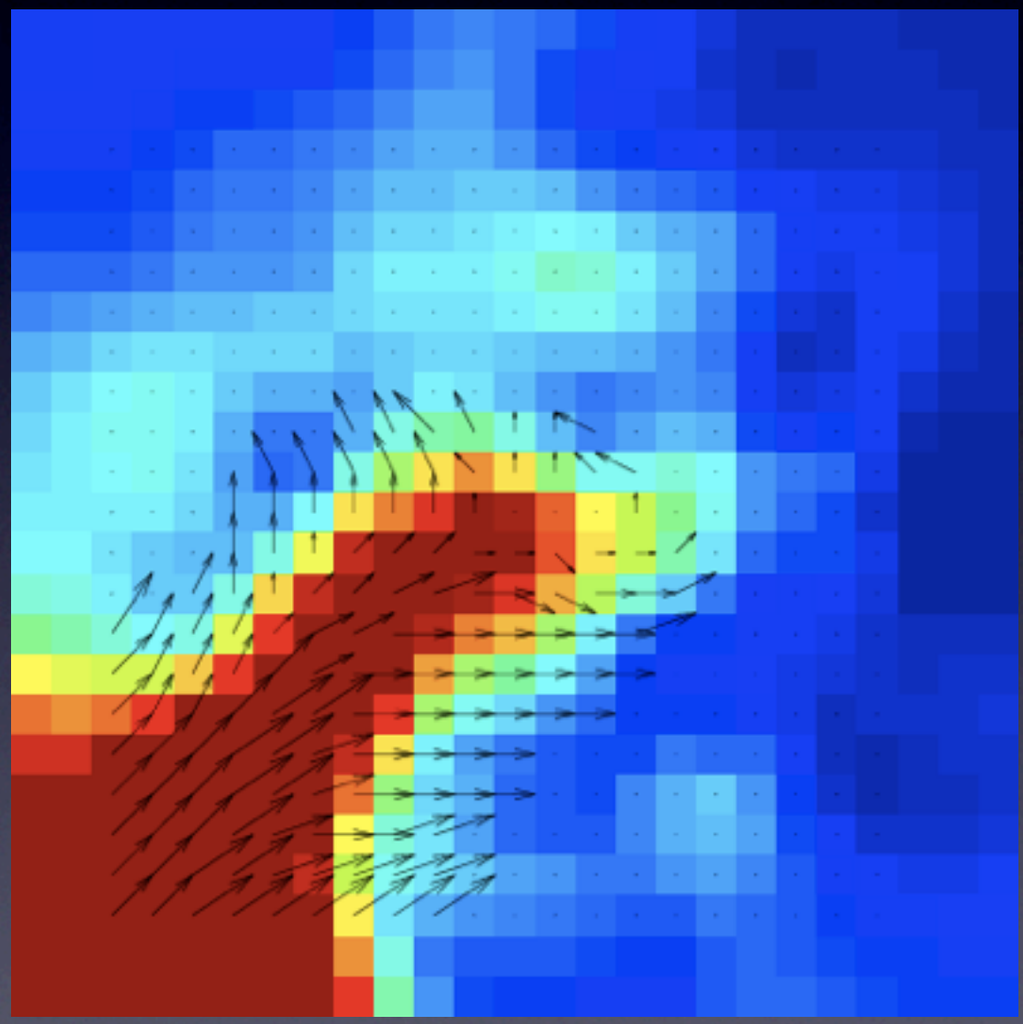
Input Sequence

What makes a blob?

- Higher than its neighbours
- Higher than the background
- Not ‘noise’

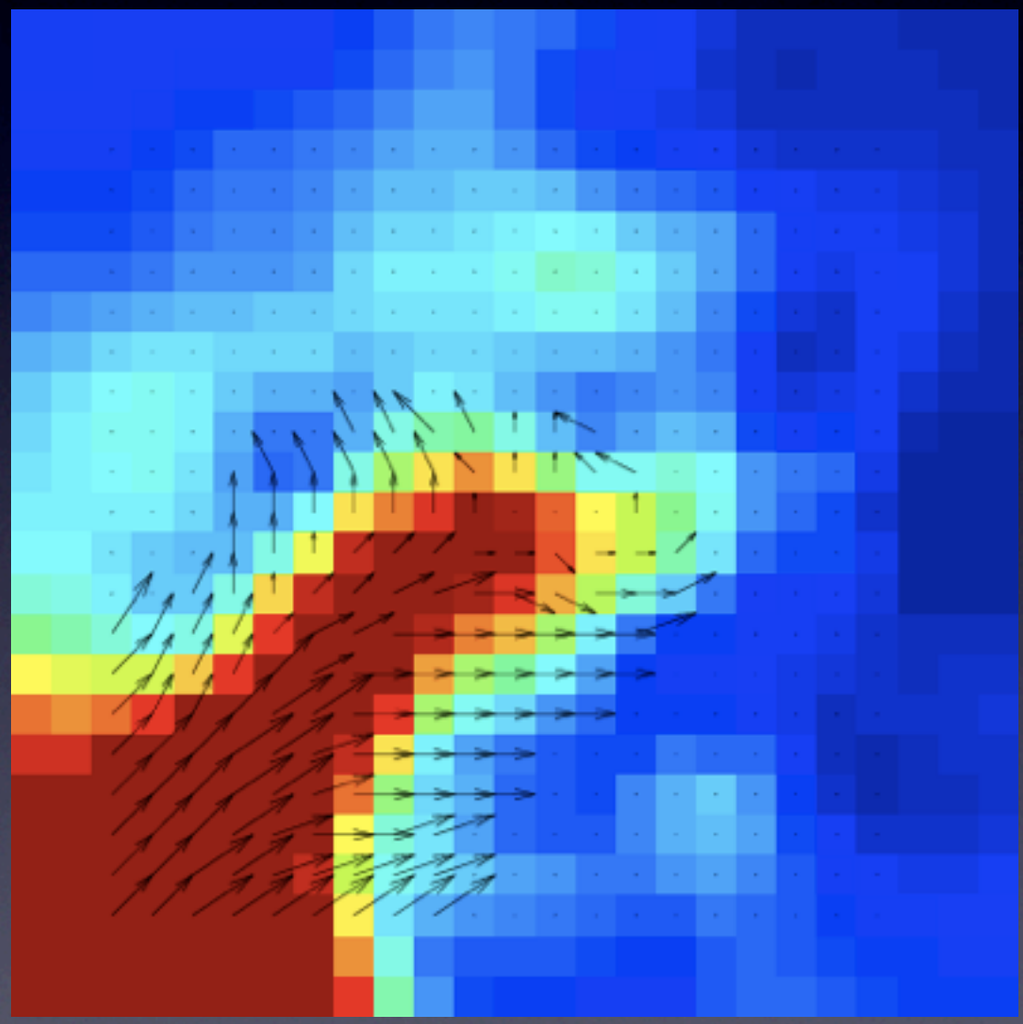


Iteration 1



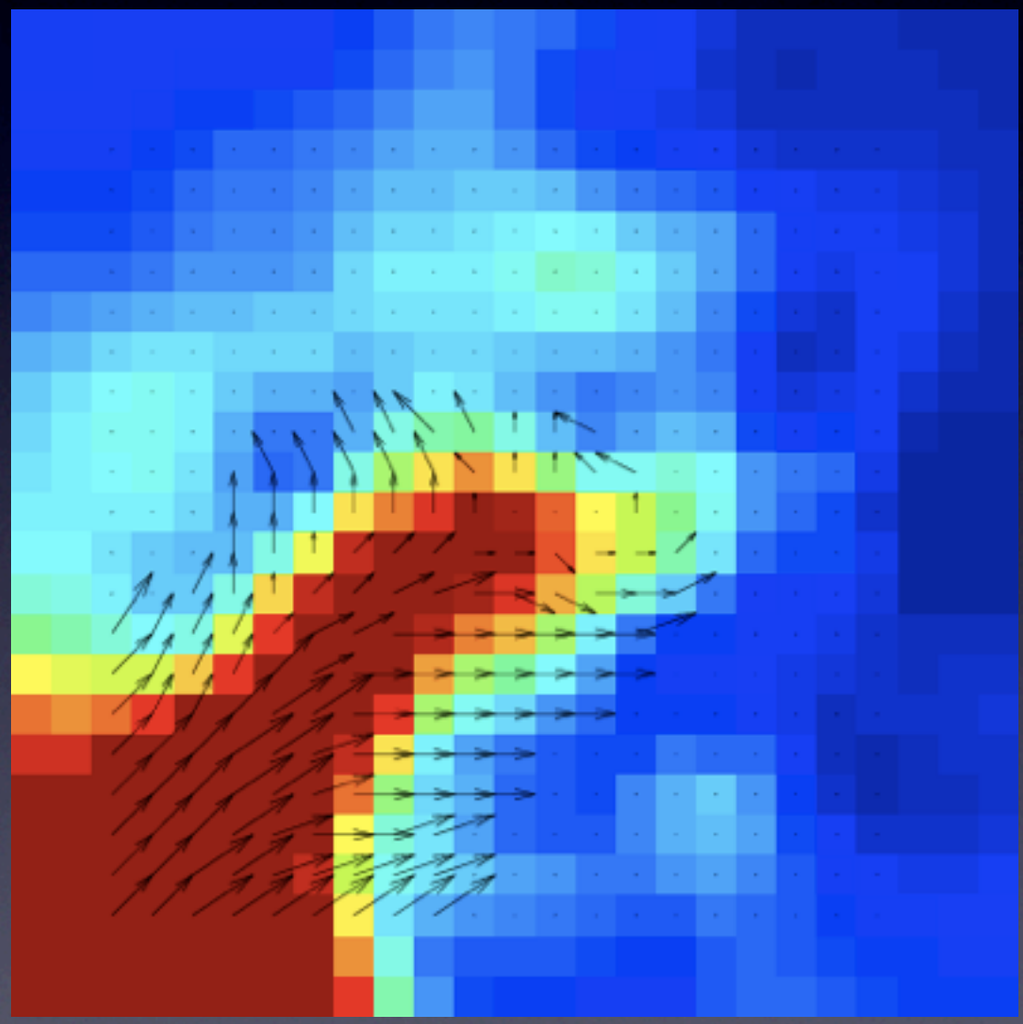
Iteration 1

- Block matching using CCC and relaxation labelling



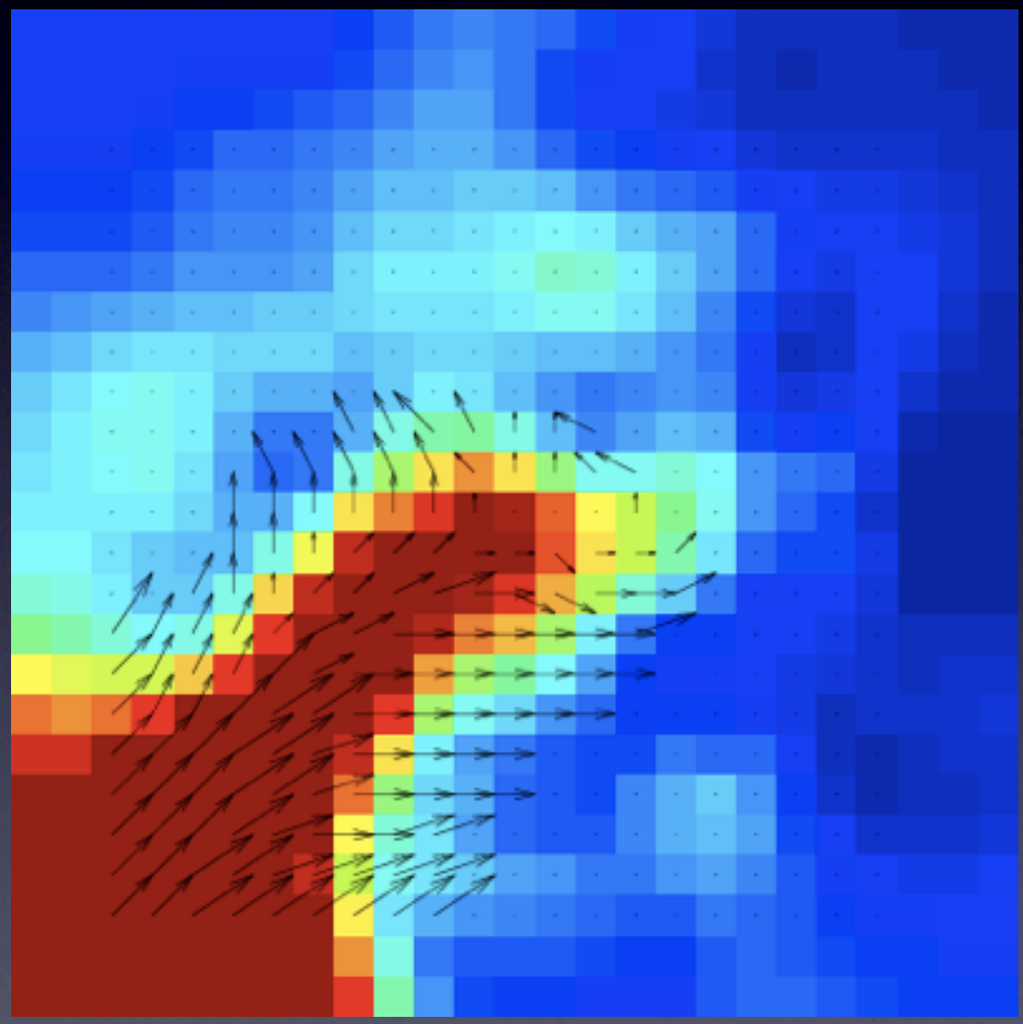
Iteration 1

- Block matching using CCC and relaxation labelling
- Thresholding by value



Iteration 1

- Block matching using CCC and relaxation labelling
- Thresholding by value
- OK sometimes



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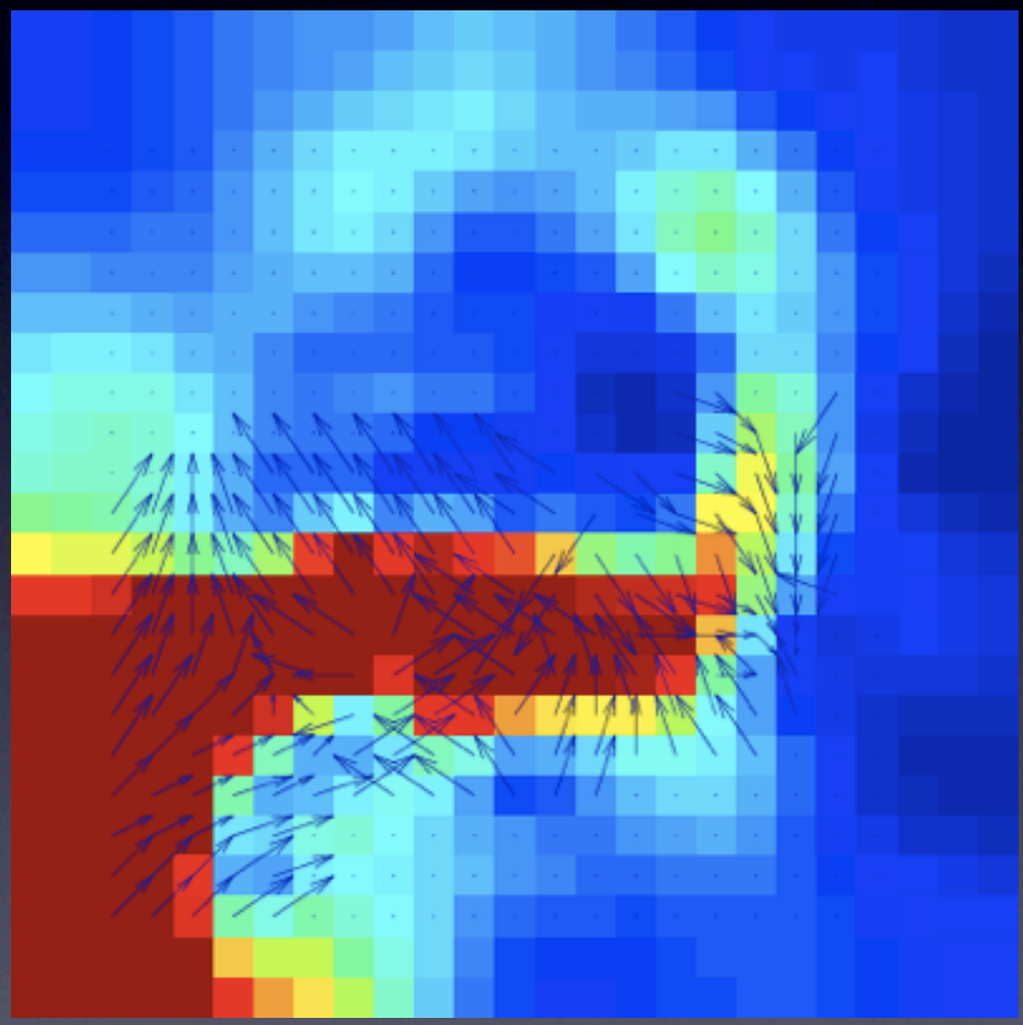
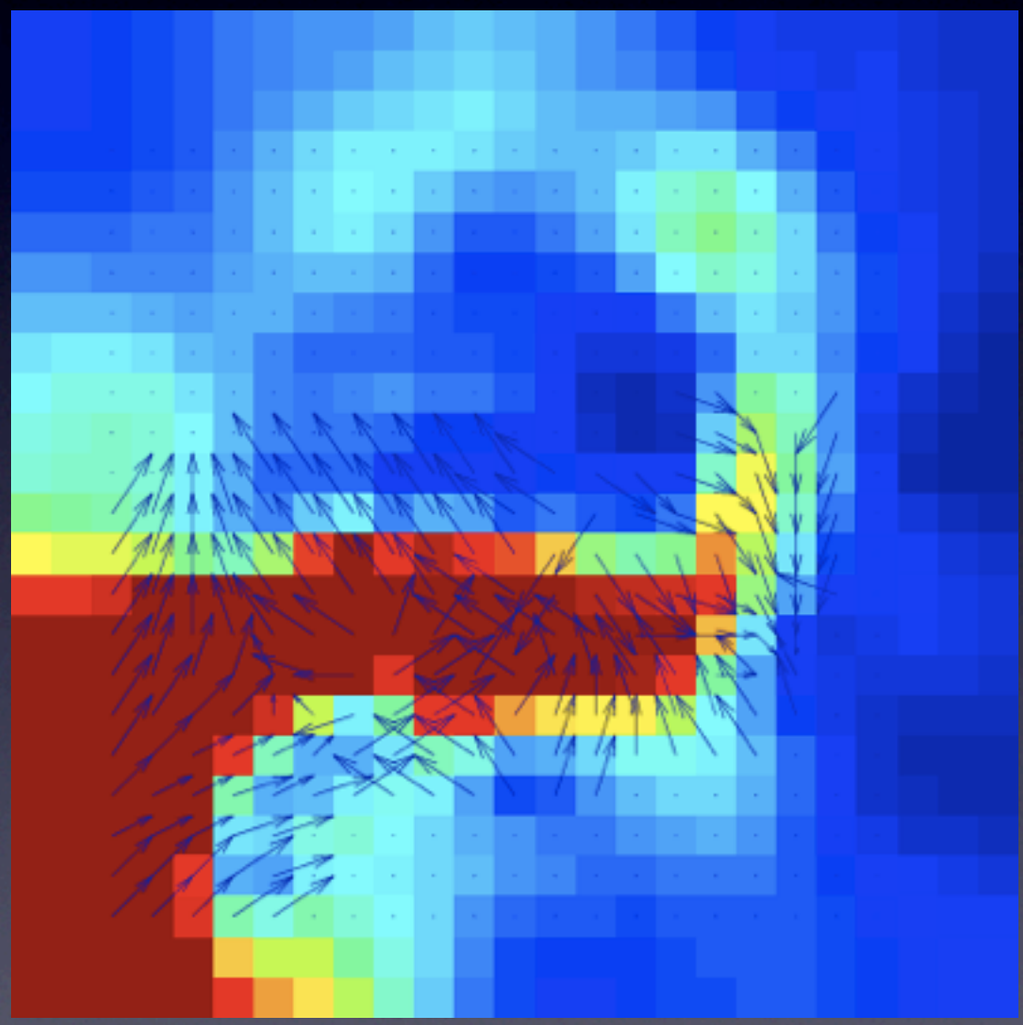


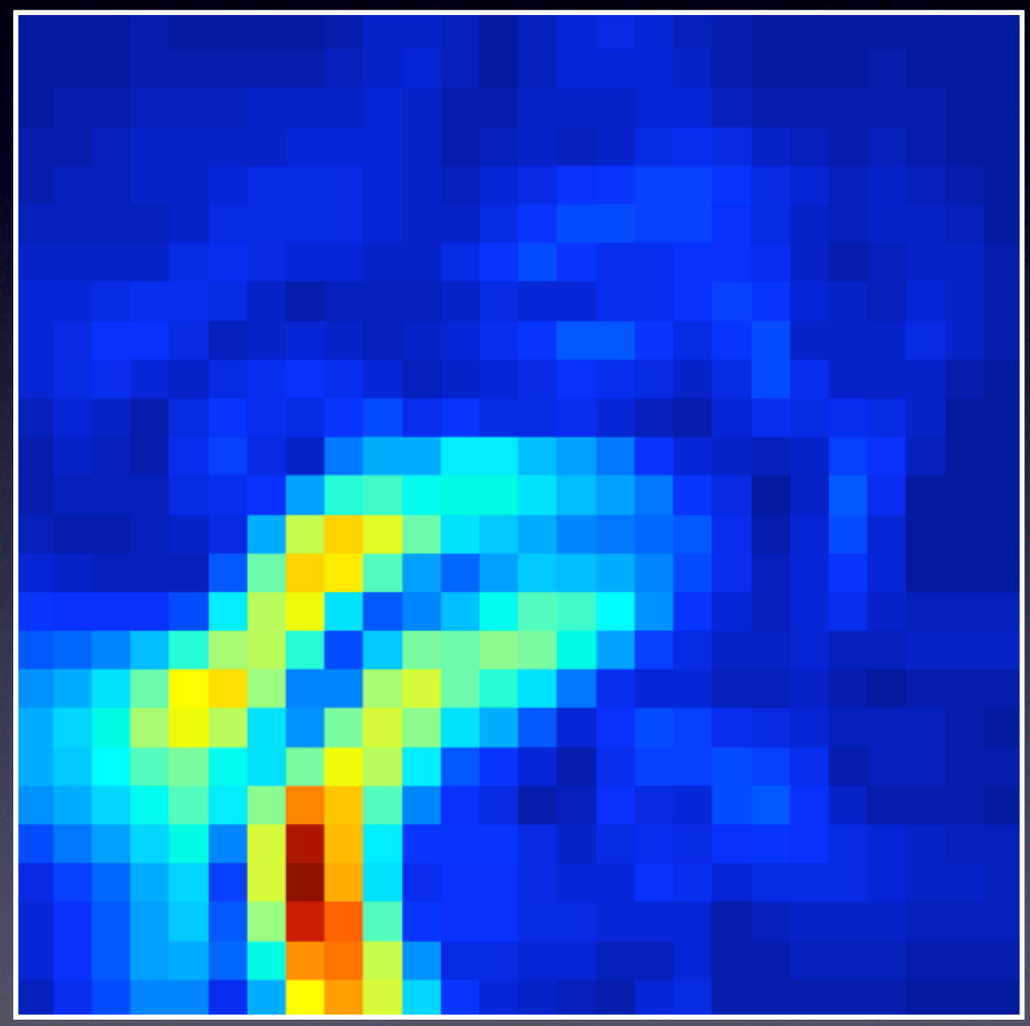
Iteration 1

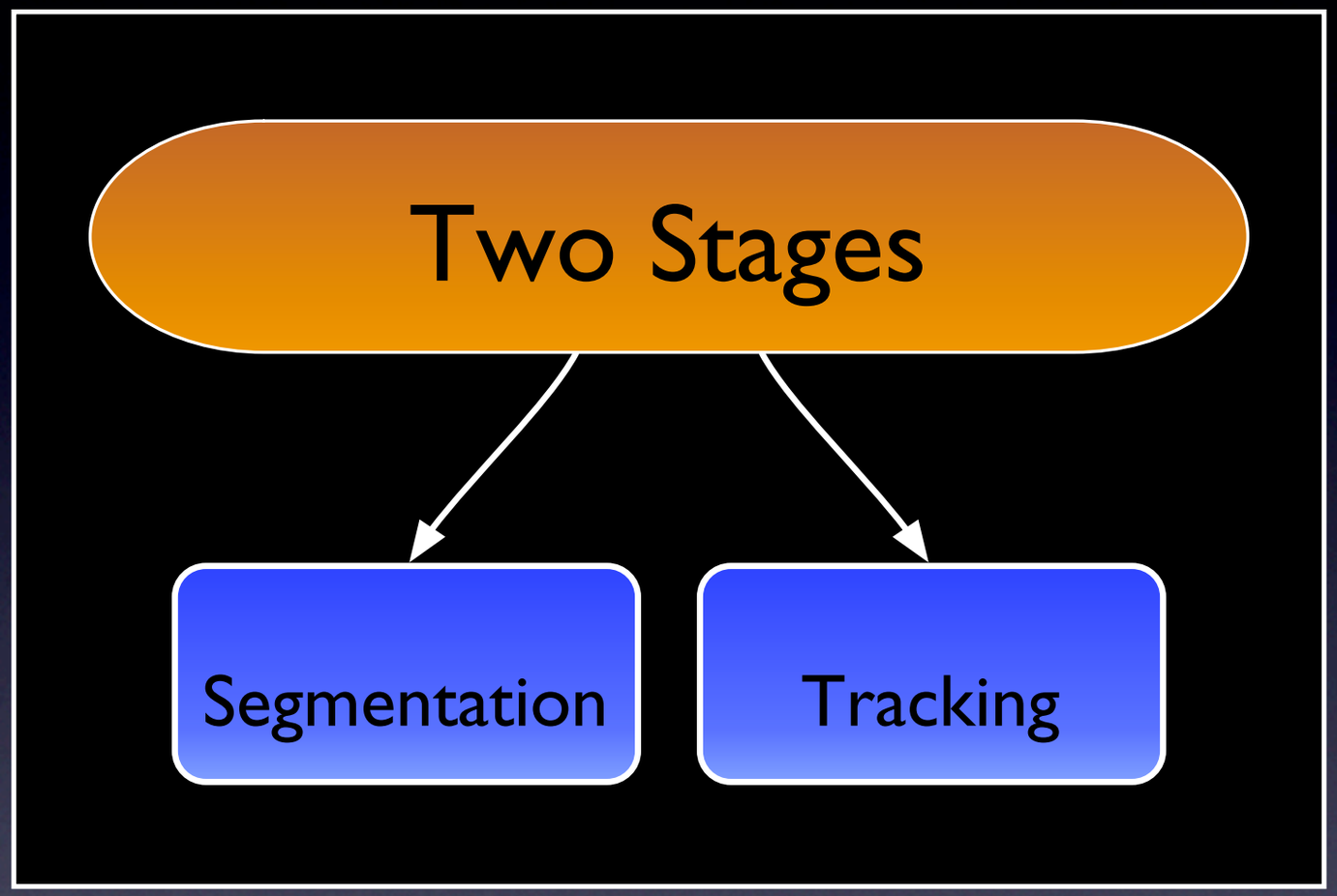
- Block matching using CCC and relaxation labelling
- Thresholding by value
- OK sometimes
- Bad sometimes



Some problems

- CCC matches too much when features are small
- Search area is small / coarse
- Sobel edges features are too small

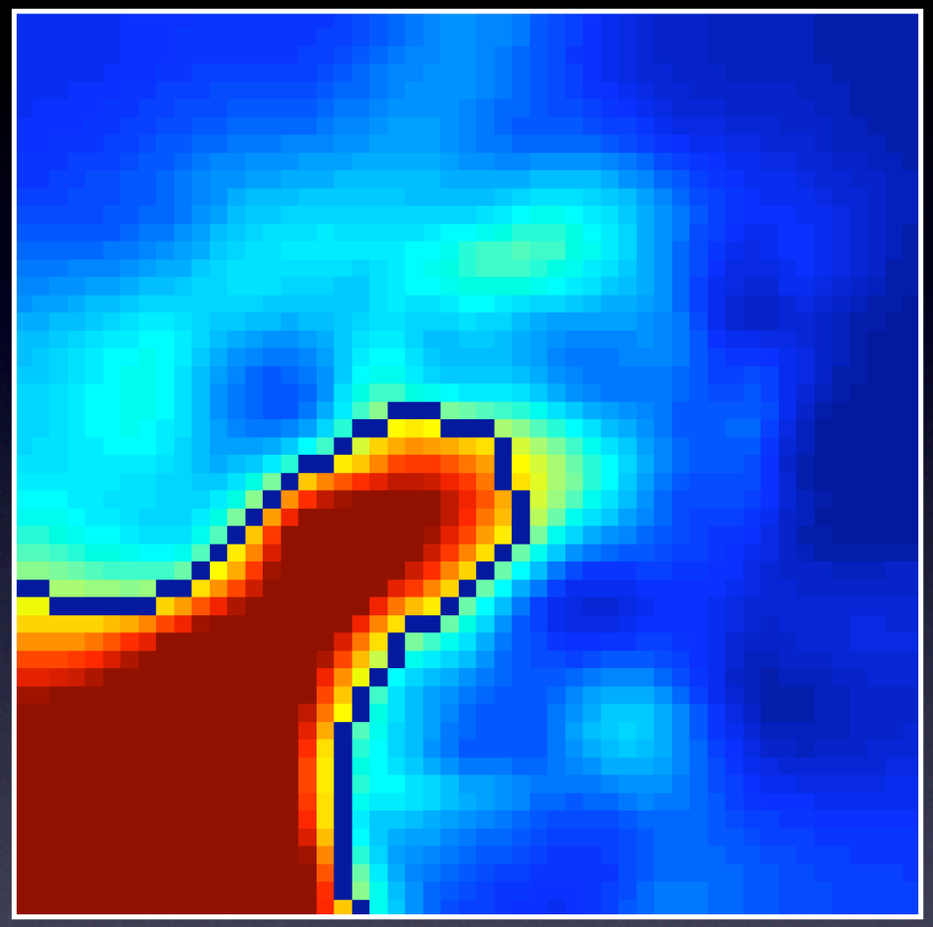




Iteration II

Segmentation I

- Starting point
  - Hand segmentation as ground truth



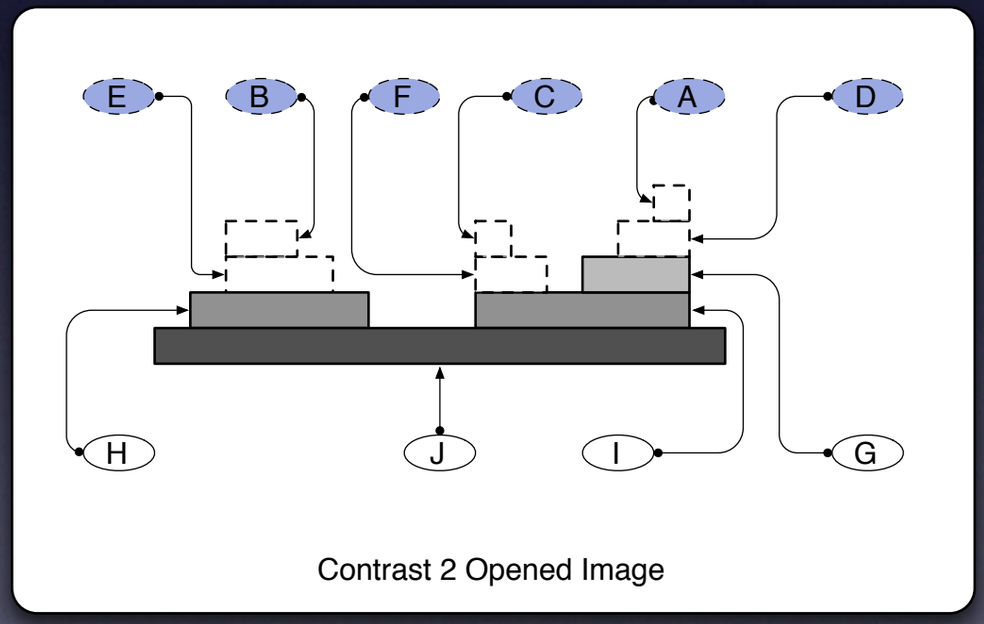
Hand Segmentation

Segmentation II

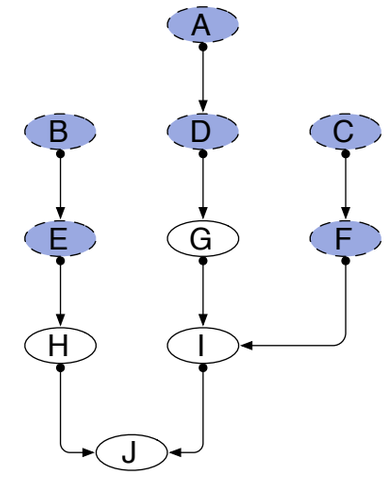
- Search for best morphological operator / parameter
  - closest to hand segmentation
- Best outputs from morphological ‘contrast closing’
  - Threshold with ‘gap filling’
  - Low sensitivity to high gradients

Attribute Morphology

- Manipulation of image level-sets based on attributes (set / image properties)



Contrast 2 Opened Image

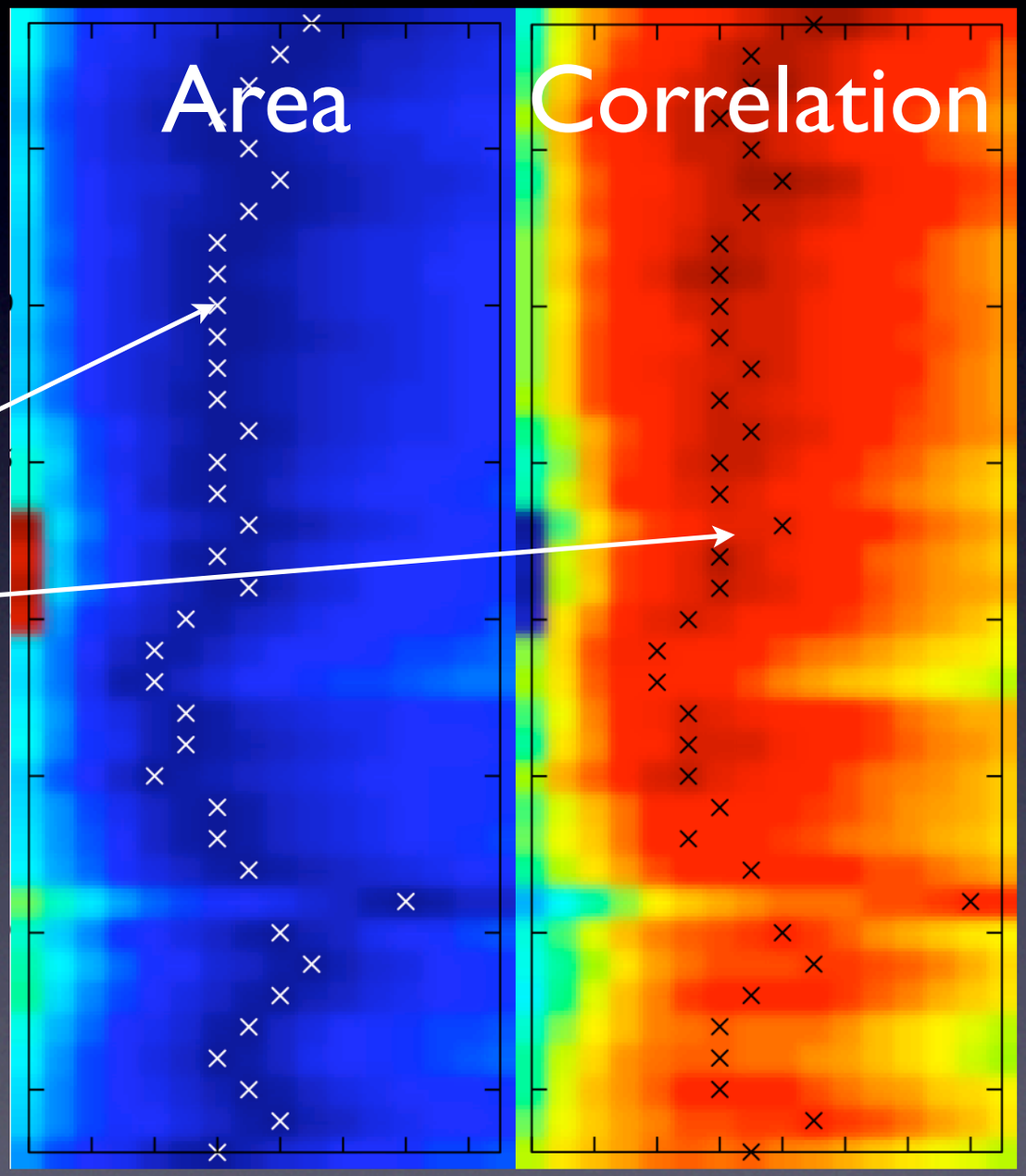


Connected Component Graph

X — Set to be removed from output image

Best Contrast

- Best contrast gives closest match to hand segmentation
- Contrast 33
- Similar when comparing areas and correlations

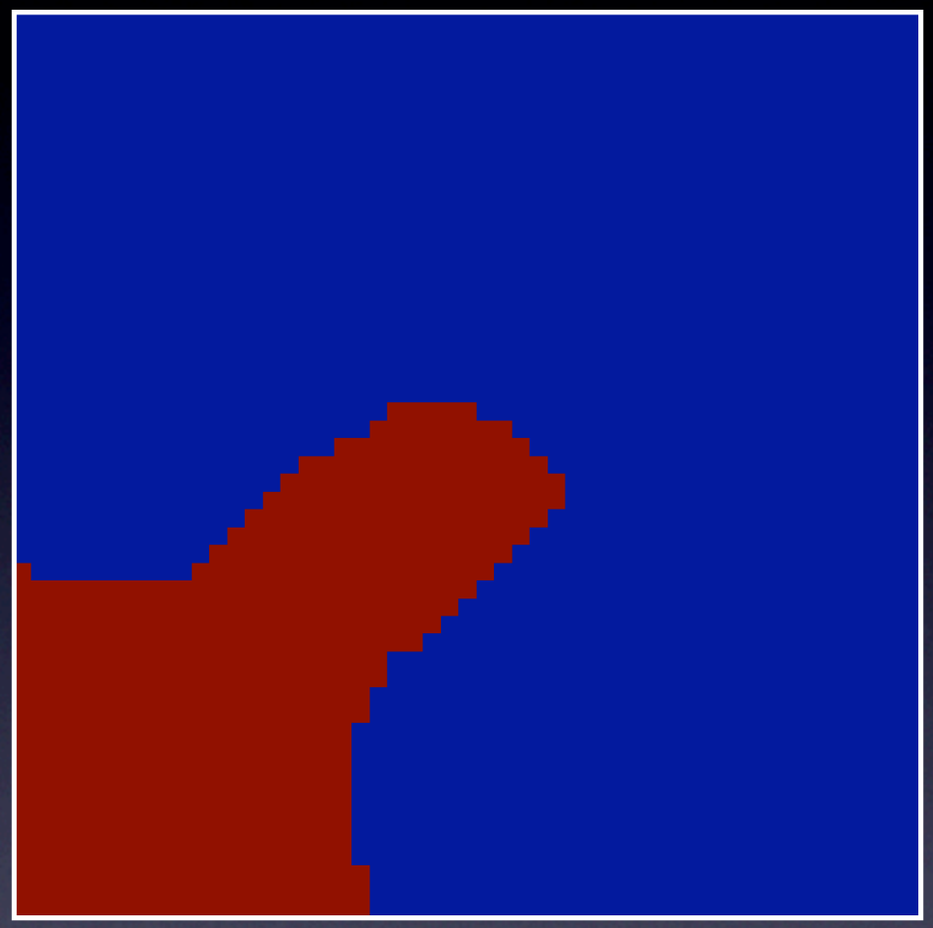


Segmentation III

- Temporal consistency is important
- Images are noisy
- Add feedback to alter contrast based on previous frames
- Improves area stability

Segmentation IV

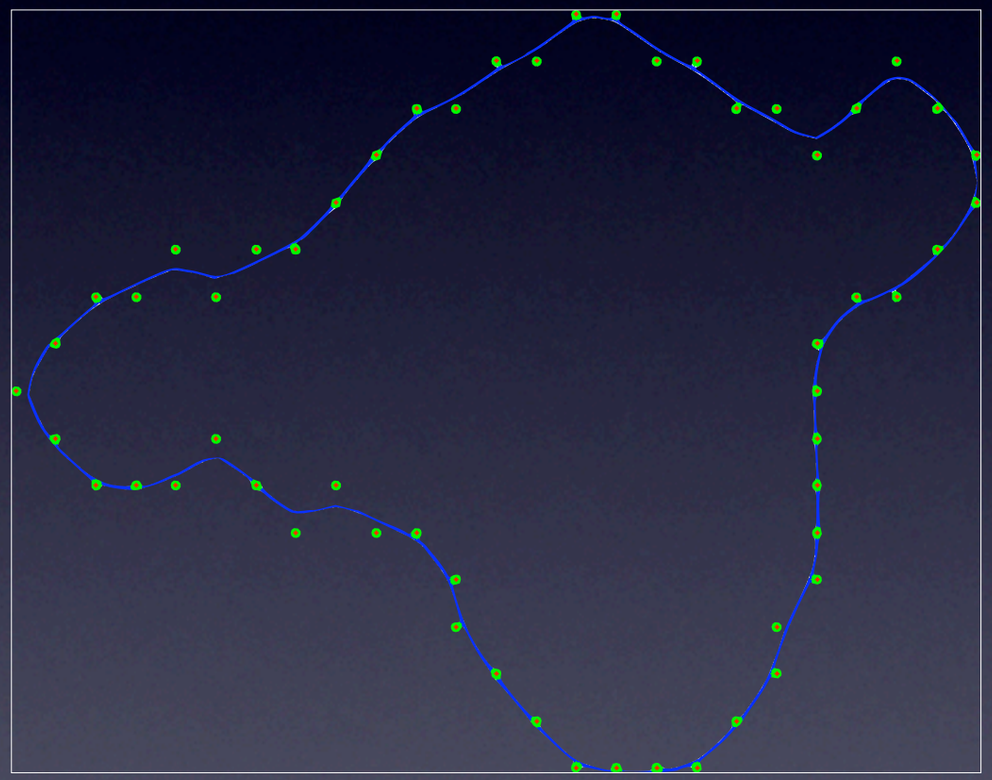
- First stage segmentation doesn't split blobs at 'saddle points'
- Use watershed transform
  - great for separating joined blobs



Segmented Output

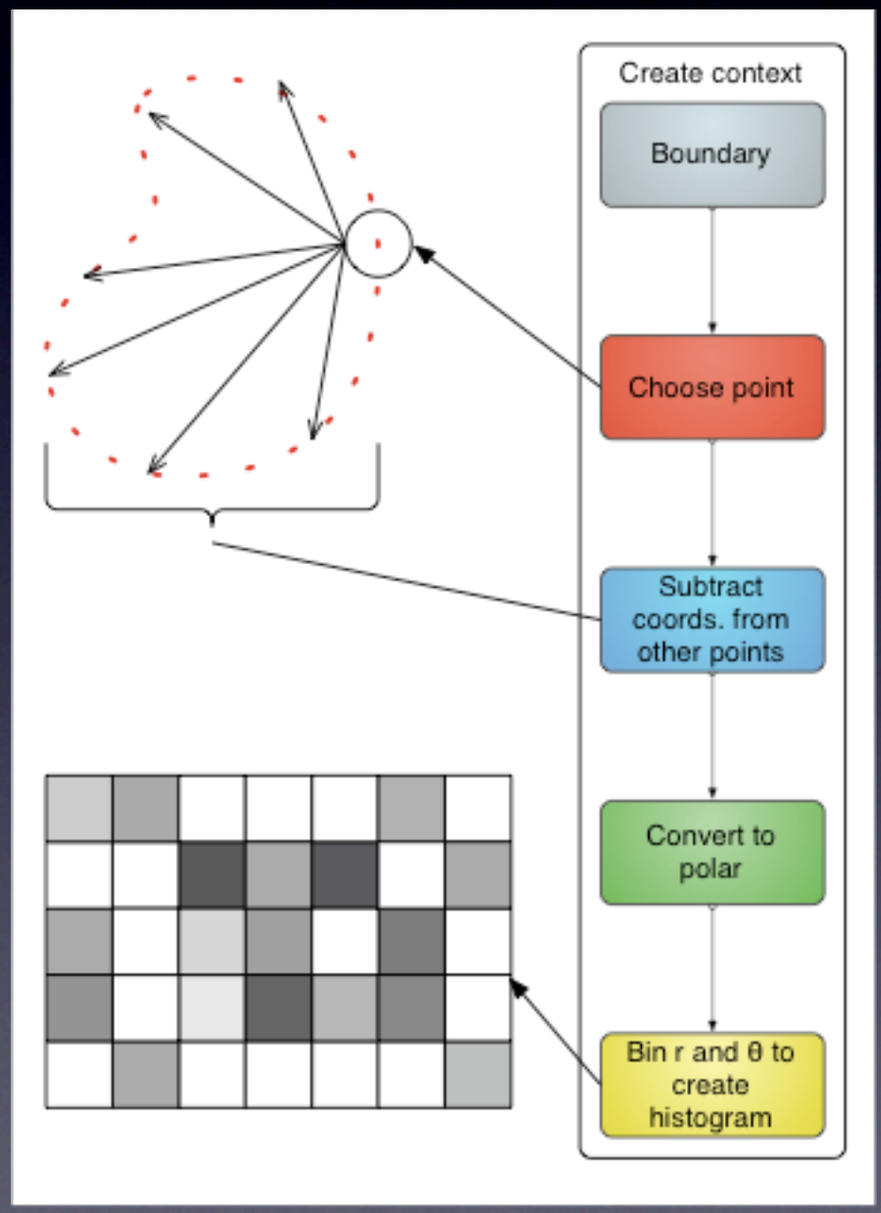
Extracting boundaries

- Use boundary tracing
  - walk around inner boundary
- Convert to smoothing spline



Shape Contexts

- Belongie et al. (PAMI 2002)
- Contexts are histograms
- Sample boundaries
- Calculate parametric mapping between them
- Vectors formed by subtracting corresponding points



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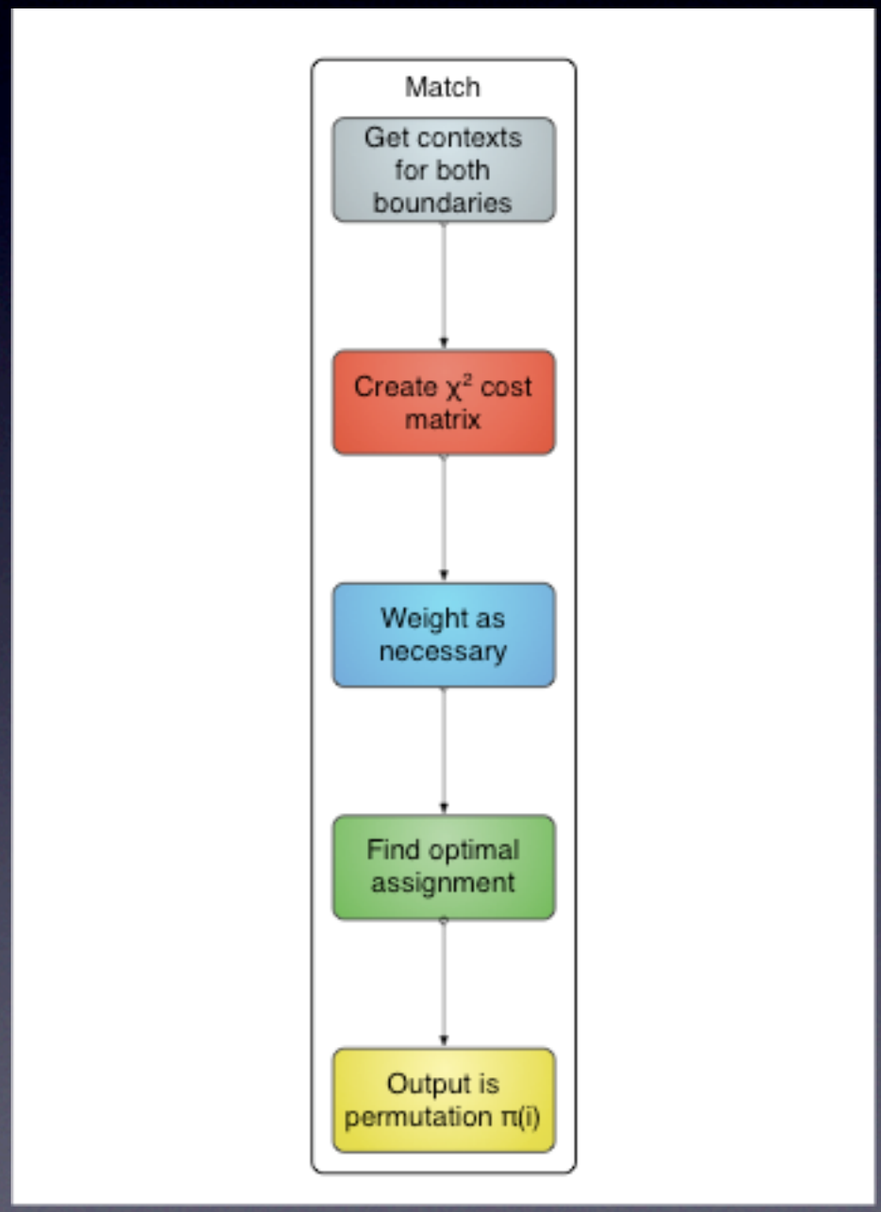


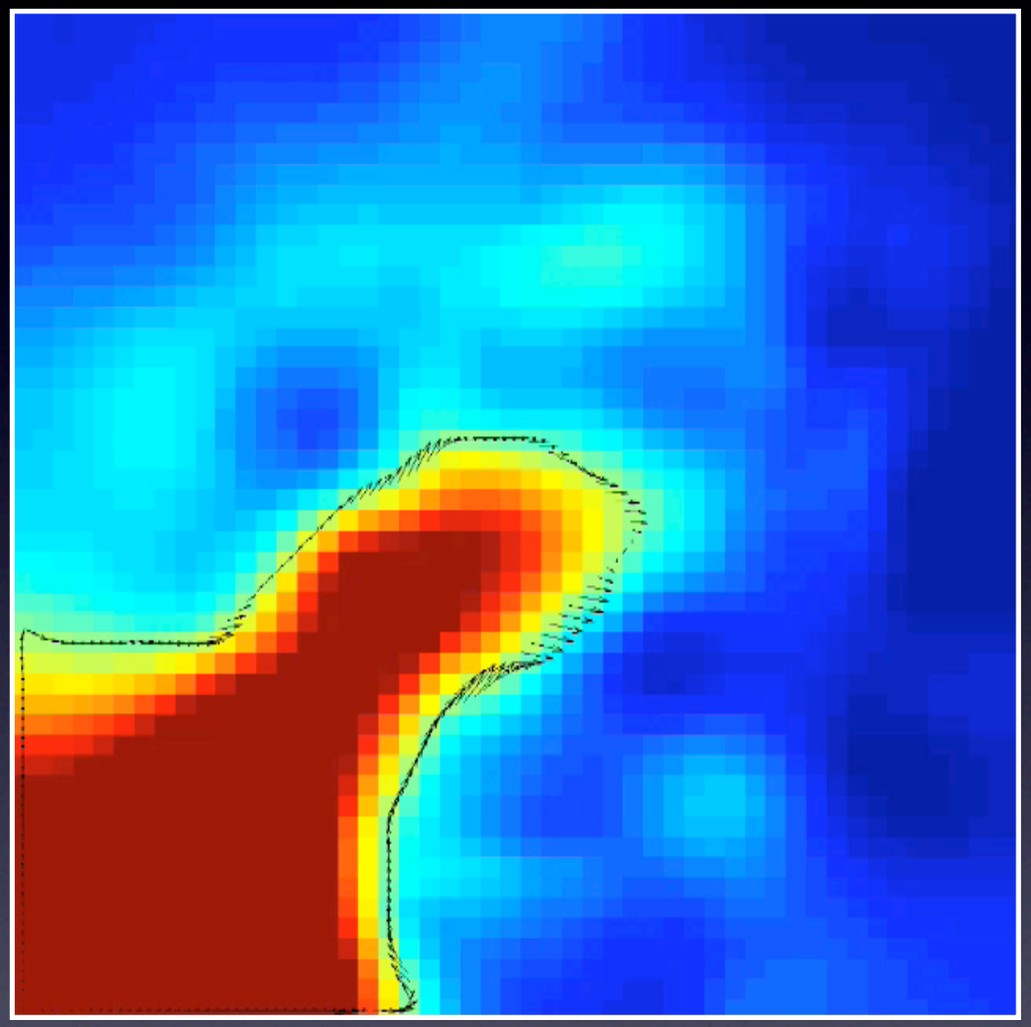
Context Pros and Cons

+

- Conceptually simple
- Easy to modify cost function
- Readily available algorithms (Hungarian)

-

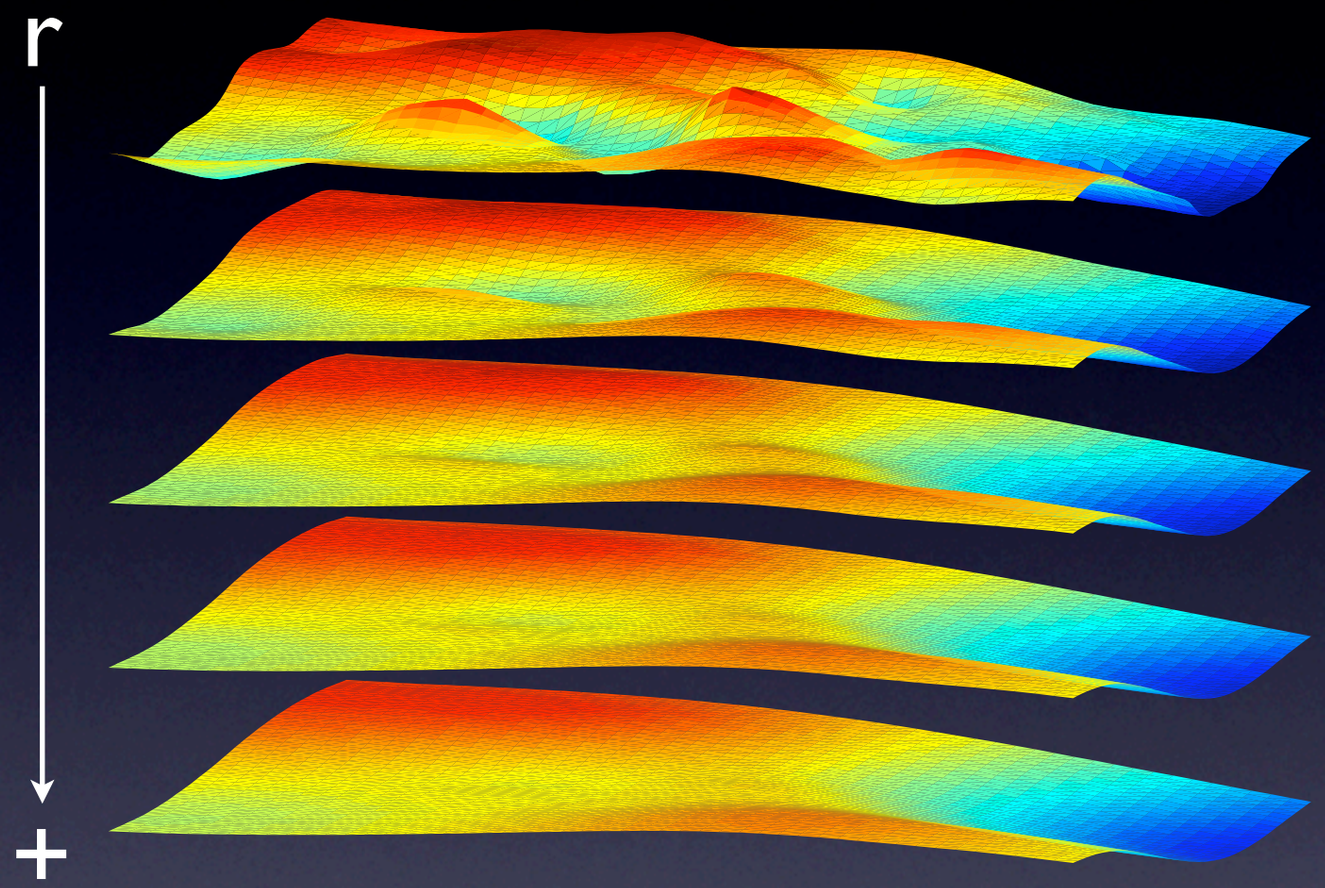
- Context matching is not scale invariant
- Boundary samples must be equal length
- 1 - 1 correspondence



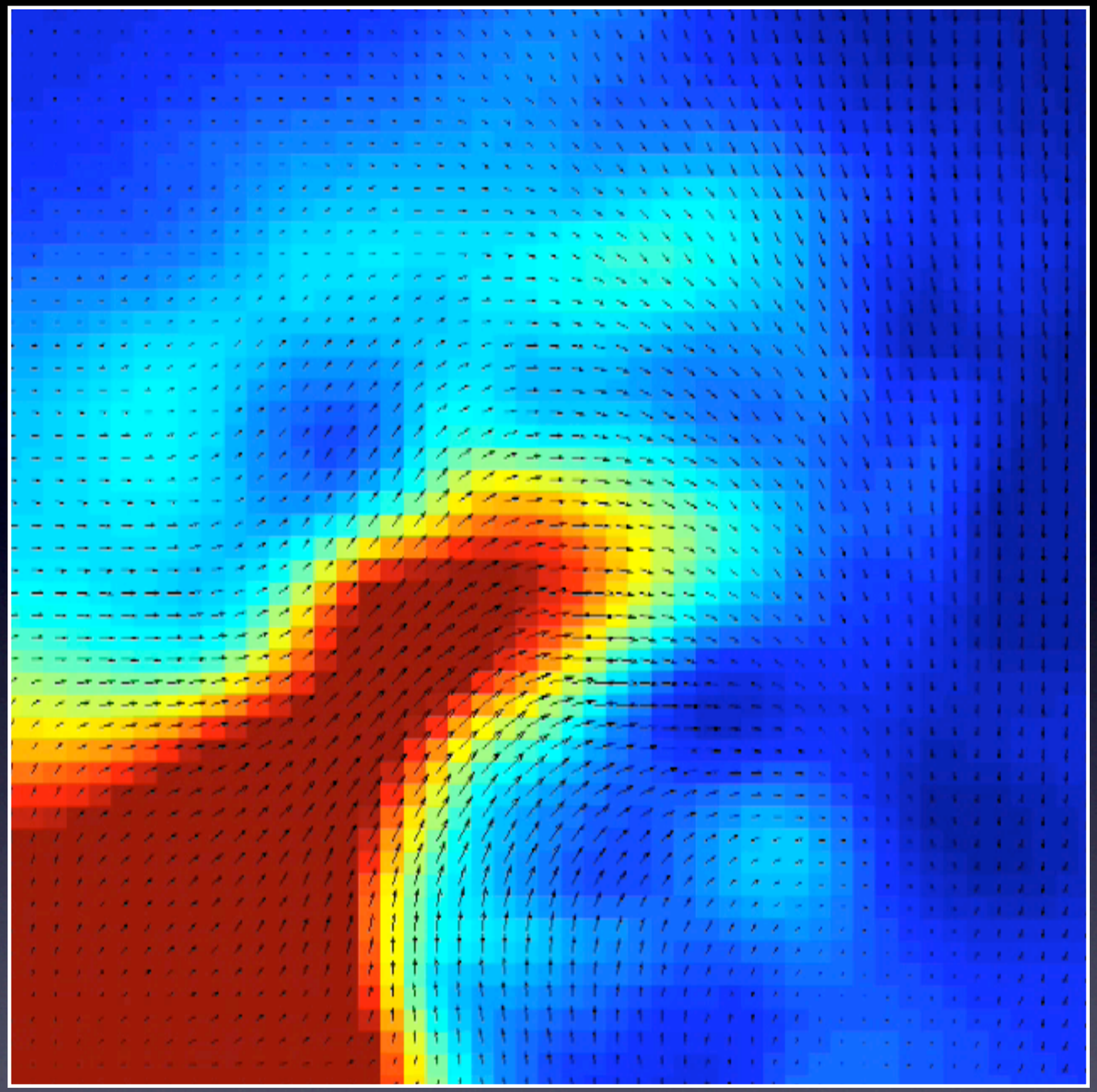
Vectors from Matching

Modelling Transformations

- Estimate plane/coordinate transformations
  - Up-sample vector field
  - Fit warping planes for *x* and *y*
  - Use RBF interpolation/fitting with optional regularisation
  - Output points are weighted combination of inputs



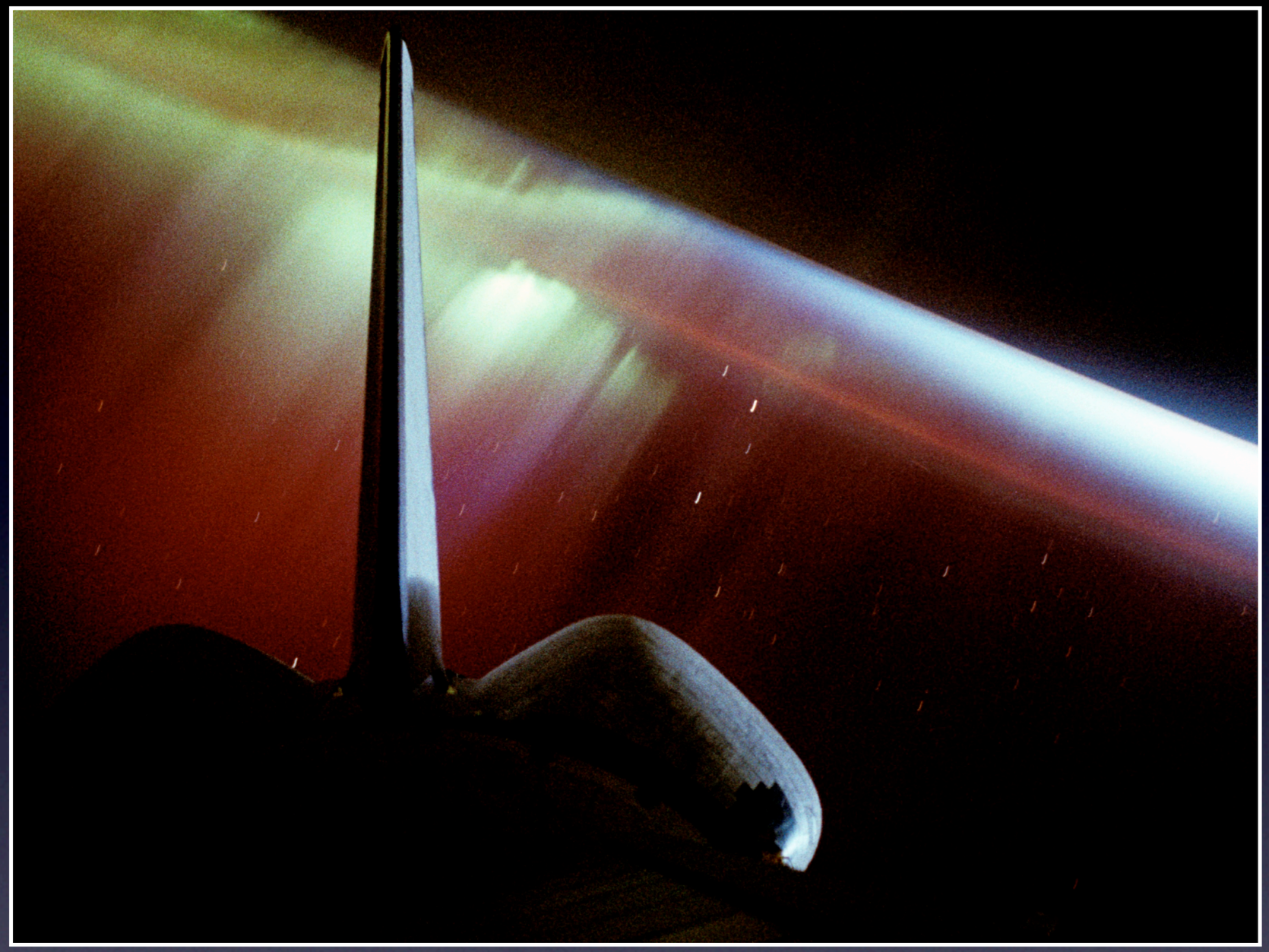
RBF Regularisation



Context Vector Fields

Next Steps

- Fitting without polynomial
  - remove background vector field
- Different bases
- Implement some kind of tracking
  - any ideas?
- Look at other areas / implementation
- Validation
  - SuperDARN



Southern Lights: NASA

Any Questions?

Extra Content

RBF Interpolation etc.

RBF Interpolation

$$f(\mathbf{x}) = p_m(\mathbf{x}) + \sum_{j=1}^{N} \lambda_j \phi(||\mathbf{x} - \mathbf{x}_j||)$$

Polynomial — Weights — Basis Function

$$\phi(r) = r^2 \log(r)$$

Then solve:

$$\begin{bmatrix} A & P \\ P^T & 0 \end{bmatrix} \begin{bmatrix} \lambda \\ c \end{bmatrix} = \begin{bmatrix} f \\ 0 \end{bmatrix}$$

$$P = \begin{bmatrix} 1 & x_1 & y_1 \\ 1 & x_2 & y_2 \\ \vdots & \vdots & \vdots \\ 1 & x_n & y_n \end{bmatrix}$$

Assignment Algorithm

- Readily available MATLAB implmentation
- Hungarian (Munkes) algorithm
- $O(N^3)$
- Traverses cost matrix with lowest possible cost

SuperDARN

- Provide daily convection maps from 11 radars in Northern Hemishpere

- Don't work very well during storms!

- http://superdarn.jhuapl.edu/