IDENTIFYING AND TRACKING STORMS IN SATELLITE IMAGES

V. Lakshmanan[1,2*], R. Rabin[1,3], V. DeBrunner[2]

[1]National Severe Storms Laboratory, Norman OK

[2]University of Oklahoma, Norman OK

[3]University of Wisconsin, Madison WI

Jan. 10-14 2000

*lakshman@ou.edu

Abstract

We use a segmentation-based approach to identify storms in images and arrange the identified storms heirarchially. A genetic-algorithm is used to match these segmented regions across frames. This method can easily handle splits and merges of storm cells and inherently handles all scales.

Current research is geared toward finding a more robust segmentation method.

The Tracking Problem

The two broad approaches to tracking storms have strengths and weaknesses:

- Correlation-based
  - Good for large scale phenomena (e.g: fronts)
  - Can not be used to track smaller scales (e.g: storm cells)
- Cell-based tracking
  - Good on isolated storms
  - Lost tracks and missed assignments a problem
  - Centroid-based methods don’t incorporate scale
  - Loses track of “big” picture

Our Approach – Hierarchial Tracking

- Combines correlation-based and cell-based approaches.
- Inherently takes the scale of the phenomena into account.
- Tracks large scales and constrains movement of smaller cells within these larger envelopes.
- Uses sophisticated global minimization under these constraints to do cell assignments.

Algorithm Overview

1. Preprocess image
2. Separate image into component regions
3. Compute region properties and relationships
4. Associate between frames

Preprocessing

- Satellite infrared image collected every 15 minutes.
- 11μ image mapped into a 0.02^o lat/lon grid.
- Pixels colder than 255K retained.
- 

Segmentation

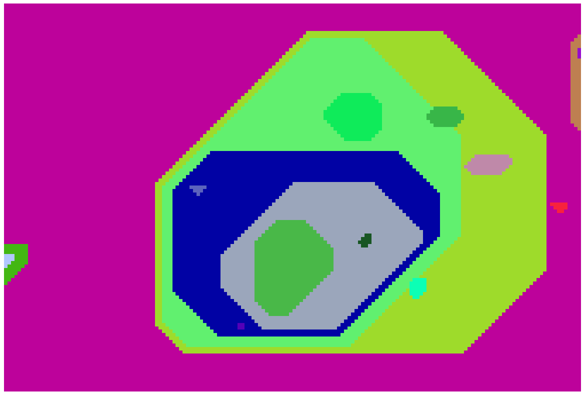
- Processing of separating image into component regions
- Suppress noise (low-pass filter)
- Grow regions that are similar:
  - Very simple test – neighborhood mean temperature within 2K
  - Very much like contouring

Segmentation

-
- We obtain connected regions.
- Prune regions that are too small.

Region Representation

- Smallest irregular convex octagon whose sides make multiples of $\pi/4$ with the image edge.
- Efficient, good representation for smaller regions.
- Captures shape and orientation of regions.



-

- Also captures relative location of smaller regions within larger areas.
- While growing region, compute statistics.
- Size, elongatedness, extent, quality of fit, etc.
- Works well on small regions, not so well on large ones, but it is much easier to associate larger regions than it is to associate small ones, so this is okay.

Frame to Frame Association

- Approach tracking as a global optimization problem.
- Use cost function that uses distance, size, shape, etc.
- Initialize at closest region to predicted location and size.
- Minimize global cost function using genetic algorithm.

Genetic Algorithm

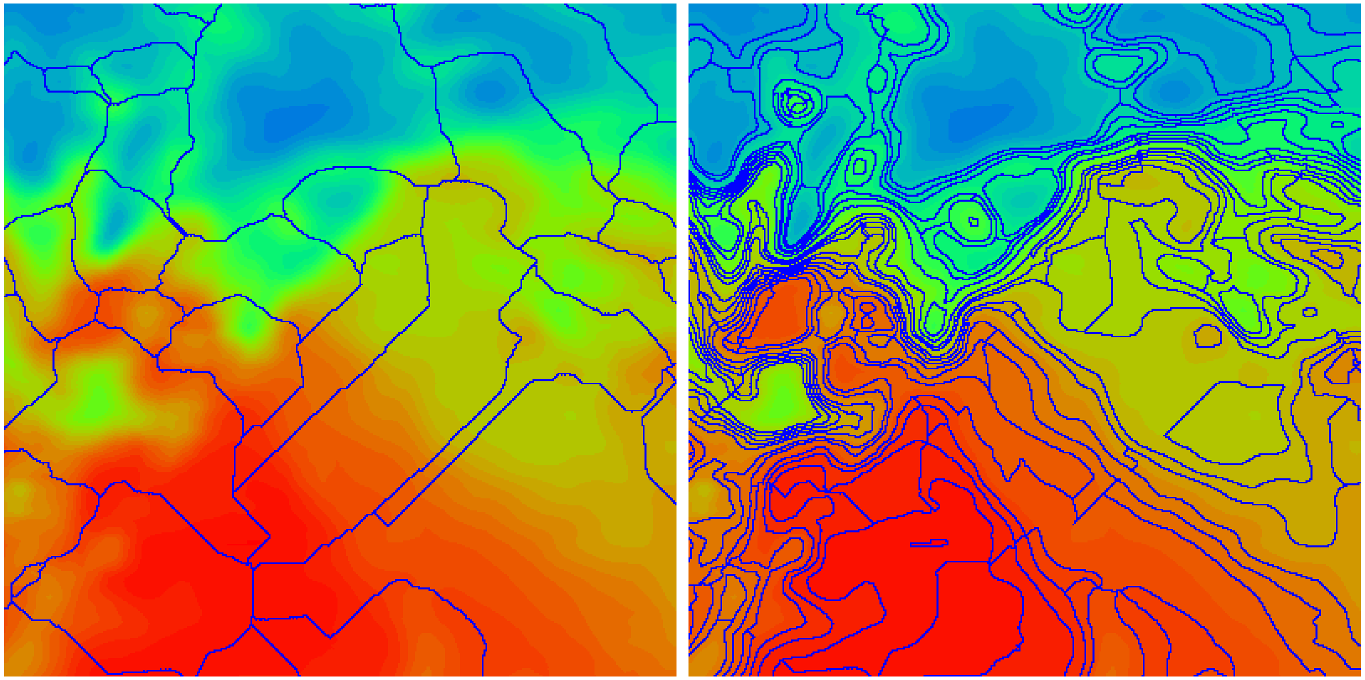
- Choose the best assignment of regions between frames ("That region in the previous frame corresponds to this region in the current frame.")
- Possiblities: all regions of suitable location and size.
- Splits and merges upto two regions are part of possibilities. (the sizes either add or divide up).
- Now choose the assignment of regions that minimizes the global cost function.
- Cost function favors long histories, similar severity, small distance, similar size and no splits.

Results

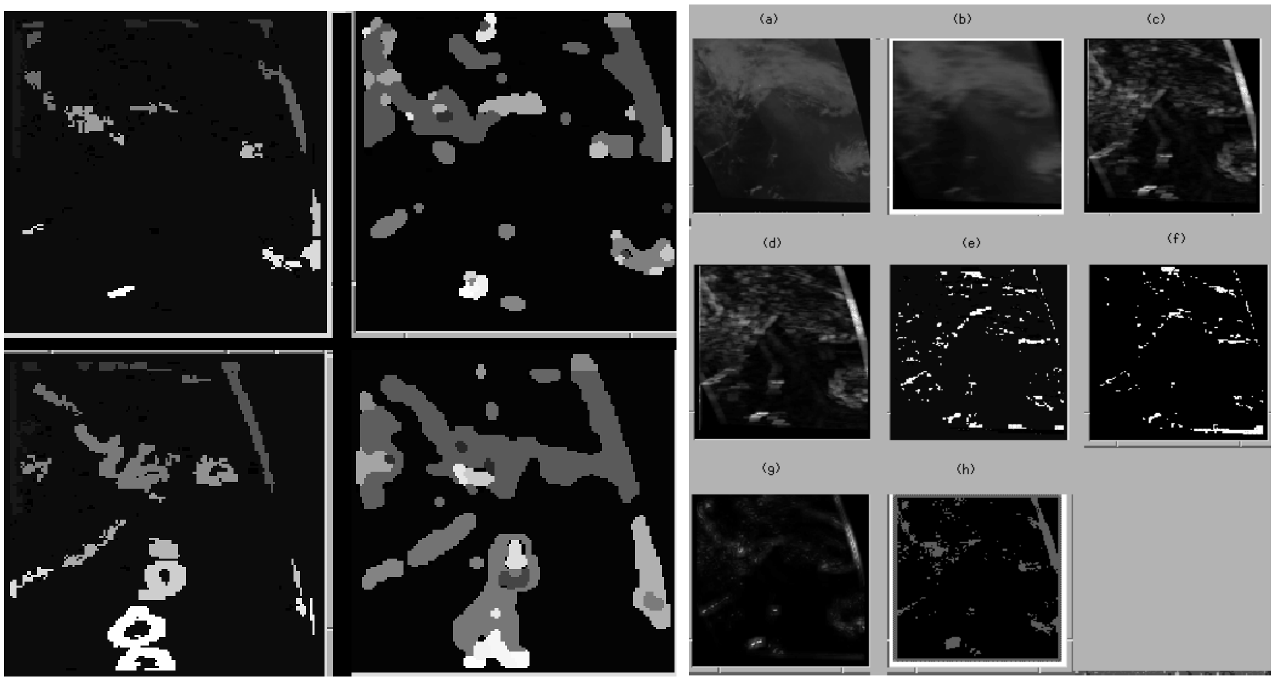
- Genetic algorithm does a good job of minimizing cost function beyond the nearest neighbor.
- Long lived storms at the larger scales.
- Problem: Contouring is not a good way to segment since storms slowly grow and decay, causing assignment problems.
- Ongoing work: Studying new methods of segmentation:

1. Watershed segmentation of smoothed field
2. Local neighborhood-based statistical segmentation

Ongoing research



- Watershed segmentation of an infrared image and contouring the same image based on watersheds.
- Watershed segmentation and contouring work very well one image at a time but are not consistent frame to frame.



- **left** The result of segmentation of two frames in the sequence after initializing the segmentation using pixels that do not lie in modal intervals. The initial segmentation map and the resulting segmentation of the first frame of the sequence are shown in the top row. The initial and resulting segmentations of a frame two hours later are shown in the bottom row.

- **right** (a) Original image (bright=higher temperature) (b) The mean in a local neighborhood around the pixel. (c) The variance in neighborhood. (d) The coefficient of variation within neighborhood. (e) Skewness within neighborhood. (f) Kurtosis within neighborhood. (g) Contrast within neighborhood. (h) Homogeneity within neighborhood.
- Neighborhood statistics (“texture”) works much better. The method is to compute the distribution of texture in regions, find outliers using the Kolomogorov-Smirnov test, combine them into new regions and iterate until the segmentation is stable.

Need more information?

- You can find other articles, an electronic copy of this poster, and a copy of the article in the AMS proceedings at this website:
  http://www.nssl.noaa.gov/˜ lakshman/Papers/
  Follow the “Conference Papers” link.

- Email me at:
  lakshman@ou.edu

References

[Dixon(1994)] Dixon, M.: , 1994: *Automated Storm Identification, Tracking and Forecasting – A Radar-Based Method*. Ph.D. thesis, University of Colorado and National Center for Atmospheric Research.

[Goldberg(1989)] Goldberg, D.: , 1989: *Genetic Algorithms in Search, Optimization, and Machine Learning*. Addison-Wesley Publishing Company, Inc., 432 pp.

[Johnson et al.(1998)Johnson, Mackeen, Witt, Mitchell, Stumpf, Eilts, and Thomas] Johnson, J., P. Mackeen, A. Witt, E. Mitchell, G. Stumpf, M. Eilts, and K. Thomas: , 1998: The storm cell identification and tracking algorithm: An enhanced WSR-88D algorithm. *Weather and Forecasting*, **13**, 263–276.

[Nering and Tucker(1993)] Nering, E. and A. Tucker: , 1993: *Linear Programs and Related Problems*. Academic Press, Inc., Boston, 275-318 pp.

[Wiklund and Granlund(1987)] Wiklund, J. and G. Granlund: , 1987: Tracking of multiple moving objects. *Time-Varying Image Processing and Moving Object Recognition*, V. Cappellini, ed., Elsevier Science Publishers B.V., 241–250.

[Wolfson et al.(1999)Wolfson, Forman, Hallowell, and Moore] Wolfson, M., B. Forman, R. Hallowell, and M. Moore: , 1999: The growth and decay storm tracker. *8th Conference on Aviation*, Amer. Meteor. Soc., Dallas, TX, 58–62.