Segmentation of Infrared Satellite Images

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June 29, 2000

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Abstract
The research that led to a robust segmentation approach is described. Segmenting a sequence of infrared satellite images using the various techniques developed is demonstrated here.
Image Description

- Satellite infrared image collected every 15 minutes.
- $11\mu$ image mapped into a $0.02^\circ$ lat/lon grid.
- Also used 4km satellite data (will be used in the later descriptions).
Simple 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
• We obtain connected regions and can prune regions that are too small.
Problems with simple approach

- Long lived storms only at the larger scales, thus causing problems at the smaller scales.

- Problem: Contouring is not a good way to segment since storms slowly grow and decay, causing assignment problems.

- Ongoing work: Developed other segmentation methods:
  1. Watershed segmentation of smoothed field
  2. Local neighborhood-based statistical segmentation
  3. Clustering of neighborhood statistics (texture).
Think of the image as a raised relief map and let water seep through from the bottom. When water from two different sources meet, call it a watershed. Mark off the connected regions between the watersheds.

Contour-based: Find out each level where the water sources meet, including the intermediate levels.
• 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.
Neighborhood statistics ("texture") works much better. The method is:

1. Compute the local distribution of various statistics around a pixel.

2. Somehow initialize the region segmentation (tried three different methods of initialization).

3. Compute the distribution of texture within the various regions.

4. Use the Kolmogorov-Smirnov test to find out whether this pixel belongs within a particular region. Constrain using Markov property – that it probably belongs in its neighbor’s region. Test for each pixel.
5. Combine outliers into new regions.

6. Iterate until the segmentation is stable.

• **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.
The idea is simple:

1. Assume that there are $k$ means in the image. We need to cluster every pixel in the image around these $k$ means.

2. Associate a vector of textural measurements with each pixel.

3. Initialize the $k$ means somehow. (I simply divided up the measurement space into equal intervals).

4. Assign the closest mean to each pixel.
5. Start iterating on the clustering scheme by reassigning pixels based on discontiguity with its neighbors (Markov assumption)

6. When stable, parcel off into contiguous regions.

7. If region is too small, choose the closest region (in measurement space) and reassign it.
Results

The K-means clustering of texture seems to solve all the problems we had with segmenting infrared satellite image sequences.

The results are reliable, do not oscillate and can be tracked. Shown on 4km data.
Markov Texture Clustering
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