Best Merge Region Growing with Integrated Probabilistic Classification for Hyperspectral Imagery

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July 28, 2011

Outline

1. Introduction
2. Proposed spectral-spatial classification scheme
3. Conclusions and perspectives

Hyperspectral image

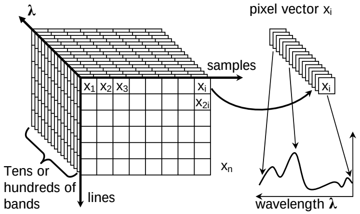
Every pixel contains a detailed spectrum (>100 spectral bands)

+ More information per pixel → increasing capability to distinguish objects

– Dimensionality increases → image analysis becomes more complex

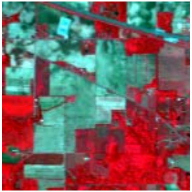
⇓

Advanced algorithms are required!



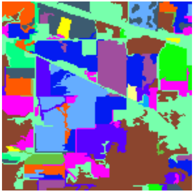
Supervised classification problem

AVIRIS image
Spatial resolution: 20m/pix
Spectral resolution: 200 bands



Ground-truth data

Task

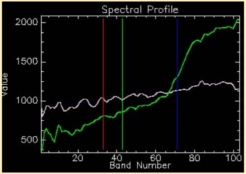


16 classes: corn-no till, corn-min till, corn, soybeans-no till, soybeans-min till, soybeans-clean till, alfalfa, grass/pasture, grass/trees, grass/pasture-mowed, hay-windrowed, oats, wheat, woods, bldg-grass-tree-drives, stone-steel towers

Classification approaches

Only spectral information

- Pixelwise approach
- Spectrum of each pixel is analyzed
- SVM and kernel-based methods
  $\rightarrow$ good classification accuracies



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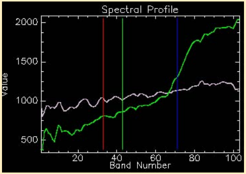
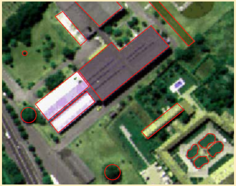


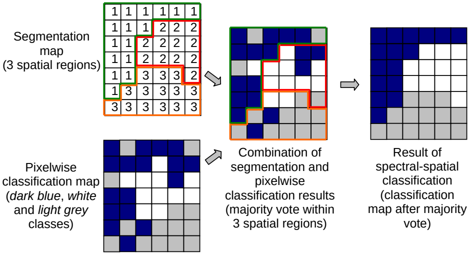
Spectral + spatial information

- Info about spatial structures is included
  - Because neighboring pixels are related
- How to extract spatial information?
- How to combine spectral and spatial information?



Our previous research

- Segment a hyperspectral image into homogeneous regions
  - Each region = adaptive neighborhood for all the pixels within the region
- Spectral info + segmentation map → classify image



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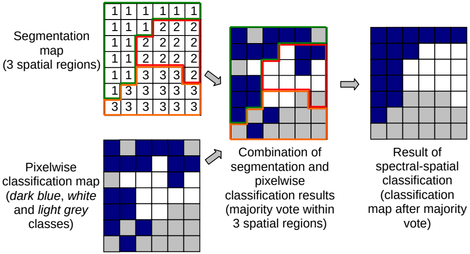
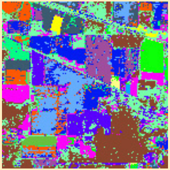


- Unsupervised segmentation: dependence on the chosen measure of homogeneity

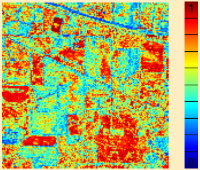
Our previous research: Marker-controlled segmentation

Probabilistic pixelwise SVM classification

Classification map



Probability map



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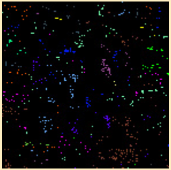
Markers = the most reliably classified pixels



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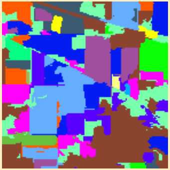
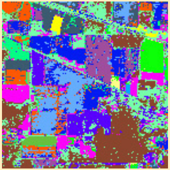
Marker-controlled region growing



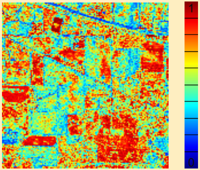
Our previous research: Marker-controlled segmentation

Probabilistic pixelwise SVM classification

Classification map



Probability map



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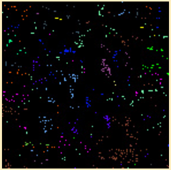

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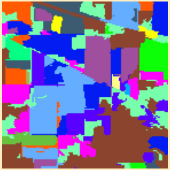
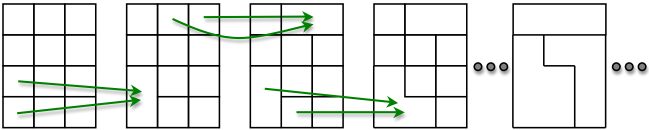


Drawback: strong dependence on the performance of the selected probabilistic classifier

Objective

- Perform segmentation and classification concurrently
  $\rightarrow$ best merge region growing with integrated classification

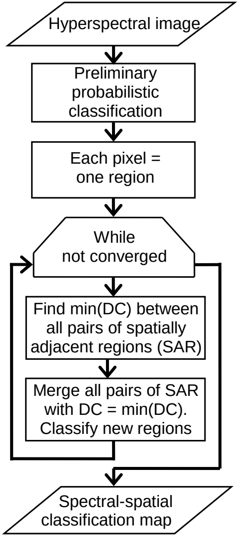


$\Uparrow$
Dissimilarity criterion?

$\Uparrow$
Convergence criterion?

Input

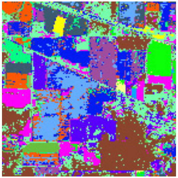
- B-band hyperspectral image
  $\mathbf{X} = \{\mathbf{x}_j \in \mathbb{R}^B, j = 1, 2, ..., n\}$
- $B \sim 100$



Preliminary probabilistic classification

- Kernel-based SVM classifier* $\rightarrow$ well suited for hyperspectral images
- Output:

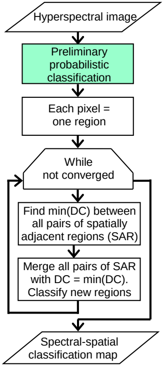
  - classification map $\mathbf{L} = \{L_j, j = 1, \ldots, n\}$



  - for each pixel $\mathbf{x}_j$:

a vector of K class probabilities

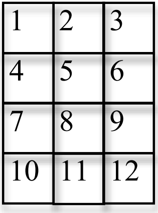
$$\{P(L_j = k|\mathbf{x}_j), k = 1, \ldots, K\}$$

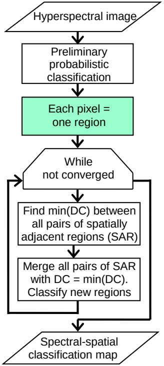


**C. Chang and C. Lin, "LIBSVM: A library for Support Vector Machines," Software available at http://www.csie.ntu.edu.tw/∼cjlin/libsvm, 2011.*

Hierarchical step-wise optimization with classification

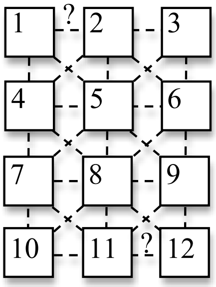
1. Each pixel $\mathbf{x}_i$ = one region R_i
   - preliminary class label $L(R_i)$
   - class probabilities $\{P_k(R_i) = P(L(R_i) = k|R_i), k = 1, ..., K\}$

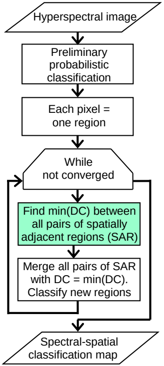




Hierarchical step-wise optimization with classification

2. Calculate Dissimilarity Criterion (DC) between spatially adjacent regions
   - DC = function of region statistical, geometrical and classification features



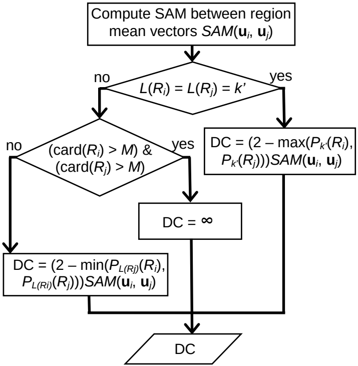


Hierarchical step-wise optimization with classification

2. Calculate Dissimilarity Criterion between adjacent regions:
   - Compute Spectral Angle Mapper between the region mean vectors u_i and u_j

$$SAM(u_i, u_j) = \arccos\left(\frac{u_i \cdot u_j}{\|u_i\|_2 \|u_j\|_2}\right)$$

   - If adjacent regions have equal class labels → they belong more likely to the same region:
     $DC = (2 - \max(P_{k'}(R_i), P_{k'}(R_j))) \cdot SAM(\mathbf{u}_i, \mathbf{u}_j)$
   - If two large regions are assigned to different classes → they cannot be merged together



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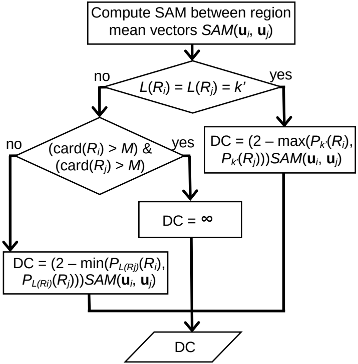

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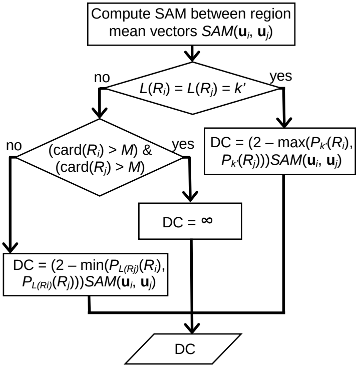

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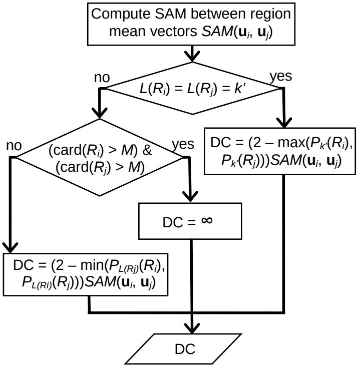

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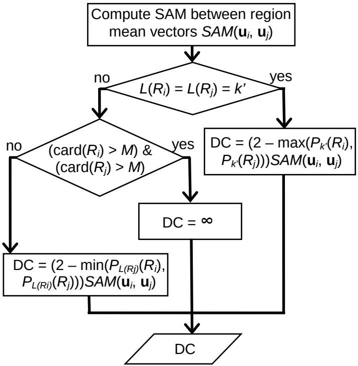
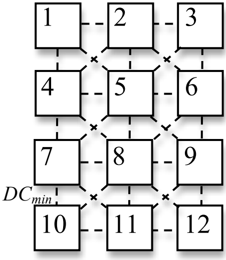
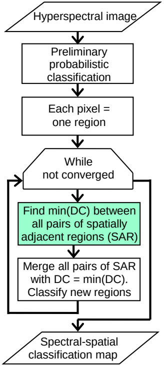
   - If adjacent regions have equal class labels → they belong more likely to the same region
   - If two large regions are assigned to different classes → they cannot be merged together
   - If two regions have different class labels → DC between them is penalized by $(2 - \min(P_{L(R_j)}(R_i), P_{L(R_i)}(R_j)))$



Hierarchical step-wise optimization with classification

3. Find the smallest dissimilarity criterion DC_{min}





Hierarchical step-wise optimization with classification

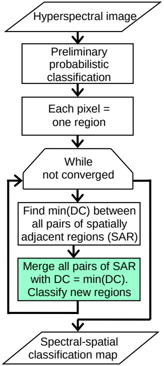
4. Merge all pairs of spatially adjacent regions with $DC = DC_{min}$.

For each new region $R_{new} = R_i + R_j$:

$$P_k(R_{new}) = \frac{P_k(R_i)card(R_i) + P_k(R_j)card(R_j)}{card(R_{new})}$$

$$L(R_{new}) = \arg\max_k \{P_k(R_{new})\}$$

All the pixels in R_{new} get a definite class label.



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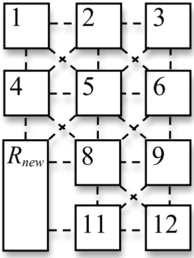
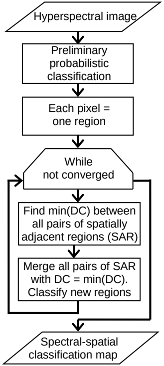
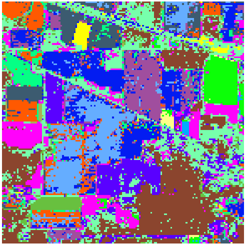


Hierarchical step-wise optimization with classification

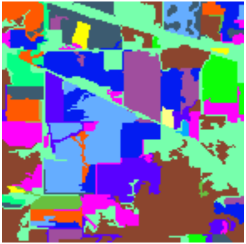
2. Calculate Dissimilarity Criterion between adjacent regions
3. Find the smallest dissimilarity criterion DC_{min}
4. Merge all pairs of spatially adjacent regions with $DC = DC_{min}$
5. Stop if all n pixels get a definite class label. If not converged, go to step 2



Classification maps



SVM



Proposed HSwC method

Classification accuracies (%)

	No. of Samp.		SVM	ECHO	SVM MSF	HSeg +MV	HSwC
	Train	Test					
Overall Accuracy	-	-	78.17	82.64	88.41	**90.86**	89.24
Average Accuracy	-	-	85.97	83.75	91.57	93.96	**94.18**
Kappa Coefficient κ	-	-	75.33	80.38	86.71	**89.56**	87.76
Corn-no till	50	1384	78.18	83.45	90.97	90.46	**93.06**
Corn-min till	50	784	69.64	75.13	69.52	**83.04**	82.53
Corn	50	184	91.85	92.39	95.65	95.65	**97.28**
Soybeans-no till	50	918	82.03	90.10	**98.04**	92.06	95.10
Soybeans-min till	50	2418	58.95	64.14	81.97	**84.04**	74.36
Soybeans-clean till	50	564	87.94	89.89	85.99	95.39	**96.10**
Alfalfa	15	39	74.36	48.72	94.87	92.31	**97.44**
Grass/pasture	50	447	92.17	94.18	**94.63**	94.41	93.96
Grass/trees	50	697	91.68	96.27	92.40	97.56	**97.85**
Grass/pasture-mowed	15	11	**100**	36.36	**100**	**100**	**100**
Hay-windrowed	50	439	97.72	97.72	**99.77**	99.54	98.86
Oats	15	5	**100**	**100**	**100**	**100**	**100**
Wheat	50	162	98.77	98.15	**99.38**	98.15	**99.38**
Woods	50	1244	93.01	94.21	97.59	98.63	**99.52**
Bldg-Grass-Tree-Drives	50	330	61.52	81.52	68.79	**82.12**	81.52
Stone-steel towers	50	45	97.78	97.78	95.56	**100**	**100**

Conclusions and perspectives

Conclusions

1. New spectral-spatial classification method for hyperspectral images was proposed
2. New dissimilarity criterion between image regions was defined
3. The proposed method:
    - improves classification accuracies
    - provides classification maps with homogeneous regions

Perspectives

- Explore further the choice of:
    - optimal representative features for segmentation regions
    - dissimilarity measures between regions

Thank you for your attention!

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