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Fuzzy Image Classification Using Multiresolution Neural Networks with Applications to Remote Sensing

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Overview

- *Incorporation of fuzziness* in training, allocation and testing stages of supervised image classification
- *Multiresolution neural network* approach: classification at different resolution levels
- *Faster implementation*: transferring of classification results to higher resolutions based on fuzziness
- *Land cover mapping* application from remotely sensed data

Fuzzy Image Classification

- Conventional *'hard' classification* techniques: each pixel is assigned a unique class
- *Fuzzy classification*: pixels may have multiple or partial class membership
- *Training stage*: training set includes an adequate number of mixed pixels with their associated class composition as the desired output of a neural network. Minimization of error between desired and actual network outputs:

$$E = \frac{1}{2}\sum_{p=1}^{P}\sum_{i=1}^{C}(d_i(x_p) - o_i(x_p))^2$$

Fuzzy Image Classification (cont.)

- *Allocation stage*: activation level of output nodes is used as measure of strength of class membership
- *Testing stage*: Euclidean distance between desired and actual network outputs used to measure classification results:

$$\overline{D} = \frac{1}{N}\sum_{n=1}^{N} D_n \ , \quad D_n^2 = \sum_{i=1}^{C} (d_i(x_n) - o_i(x_n))^2$$

- Fuzziness can also be accommodated in *Bayesian classifier*, or used with *fuzzy c-means* clustering

Multiresolution Decomposition

- Fuzzy classification data obtained at different resolution levels by multiresolution decomposition of both the original image and its classification representation
- Possible use of data acquired from satellite sensors at two or more spatial resolutions
- *Approximation* of image x_0 at resolution j = -1

$$x_{-1}^{LL}(m,n) = \sum_{k=1}^{N}\sum_{l=1}^{N} h_L(2m-k)h_L(2n-l)x_0(k,l)$$

Multiresolution Decomposition (cont.)

- *Perfect reconstruction* of x_0 possible through synthesis of subband components (*approximation* image x_{-1}^{LL} and *detail* images x_{-1}^{LH}, x_{-1}^{HL} and x_{-1}^{HH})
- *Approximate reconstruction* possible by using the low resolution component only:
  $$\hat{x}_0(m,n) = \sum_{k=1}^{N/2} \sum_{l=1}^{N/2} h_L(m-2k) h_L(n-2l) x_{-1}^{LL}(k,l)$$
- *Optimal design* for analysis and synthesis filters that minimize MSE between original image and its low resolution representation

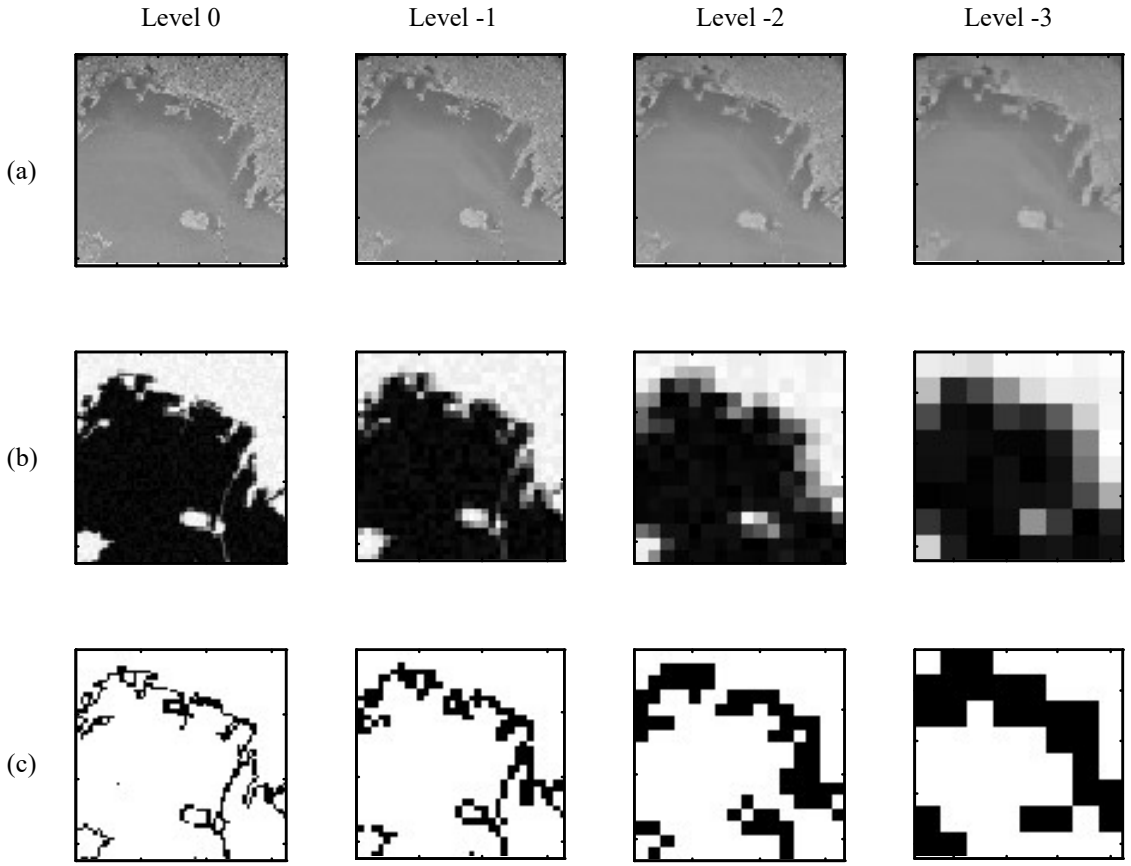
Hierarchical Neural Network Classification

- *Training stage*: feedforward multilayer network trained to classify approximation image at resolution level j<-1
- Training continues at level j+1, by transferring a large number of weights between input and 1st hidden layer to the higher resolution network
- *Allocation stage*: classification starts at low resolution and stops at level j if 'hard' results (near '0' or '1') are derived. Continues at level j+1 if results are 'fuzzy' (not near '0' or '1')

Experimental Results

- *Land cover mapping* application from aerial images - *two classes* (land and sea)
- Image segmented in 8x8 blocks - 64 *DCT coefficients* used for block classification
- *Land cover map* manually derived for level 0. Approximations derived for levels 1 through -3
- Feedforward neural network with 1 hidden layer trained independently at levels 0 to -3.
- 85% reduction in computational time, with 10% decrease in classification accuracy

Experimental Results (cont.)



Classification results: (a) input images, (b) classifier output, (c) regions corresponding to ‘fuzzy’ classification

Conclusions - Further Work

- Multiresolution hierarchical neural network approach to supervised classification, exploiting fuzziness of classification results
- Transferring classification results to higher resolutions can lead to faster implementation
- Significant improvement in classification speed without deterioration of representation accuracy
- Application of fuzzy classification to other problems (indexing and content-based retrieval from image and video databases)