MULTISCALE IMAGE PROCESSING AND STATISTICAL MODELING FOR IMAGE INTERPRETATION

Sinisa Todorovic

Department of Electrical and Computer Engineering

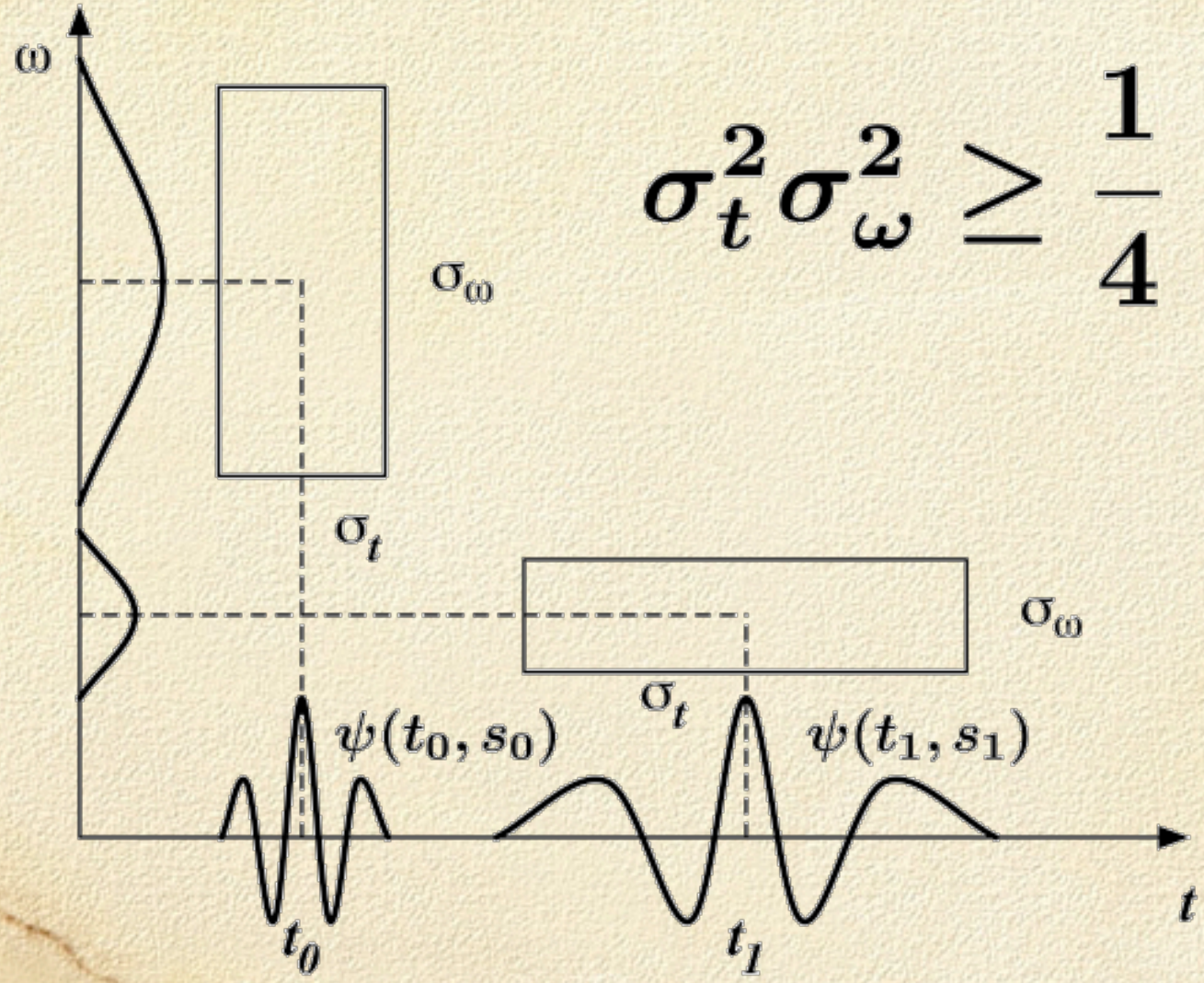
University of Florida

Machine Intelligence Laboratory

Department of Electrical and Computer Engineering

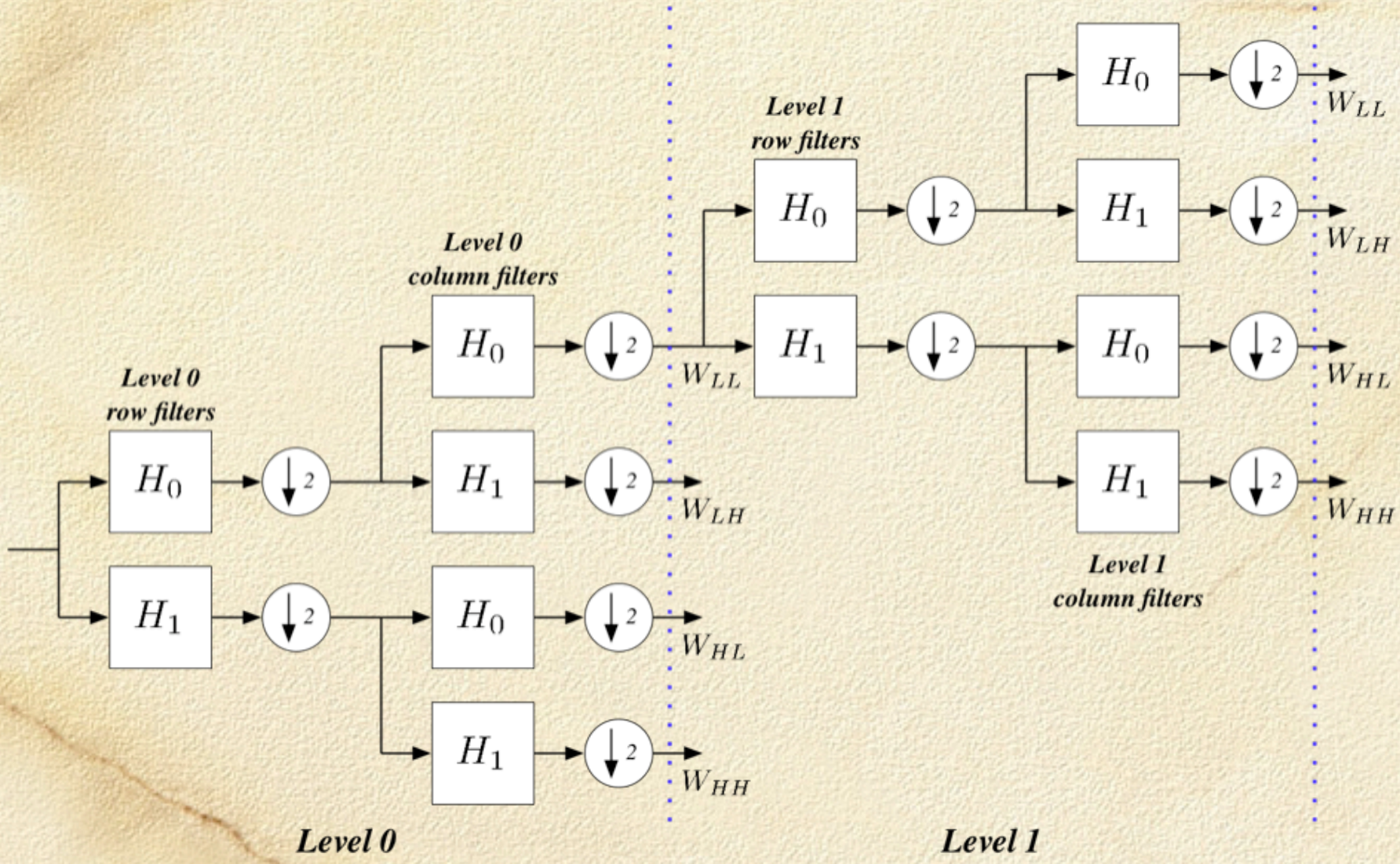
UNIVERSITY OF FLORIDA

Wavelet Functions

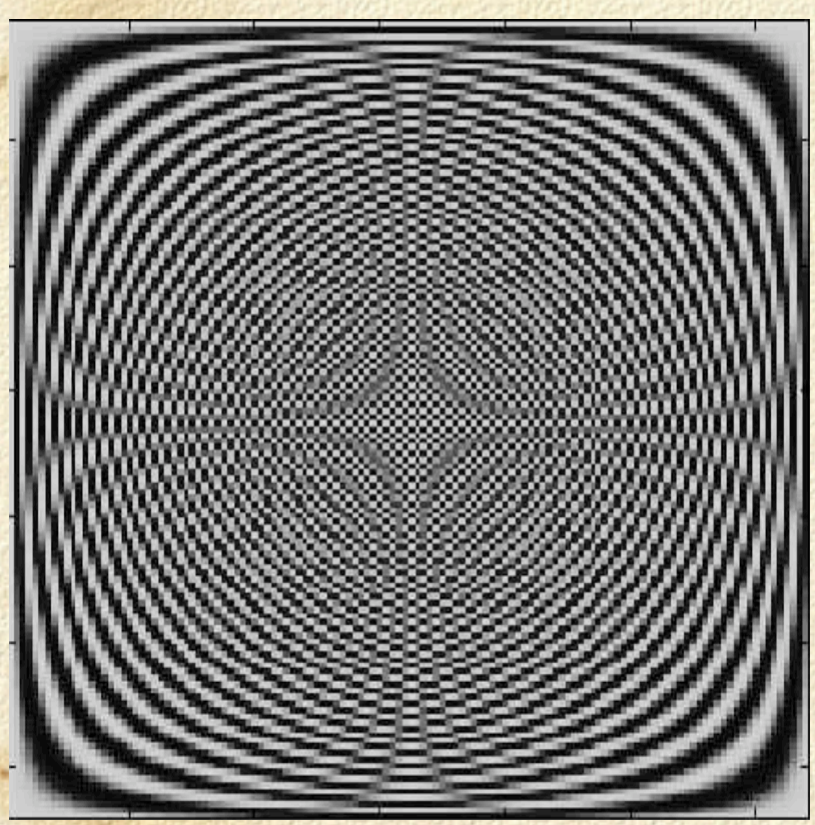


$$\sigma_t^2 \sigma_\omega^2 \geq \frac{1}{4}$$

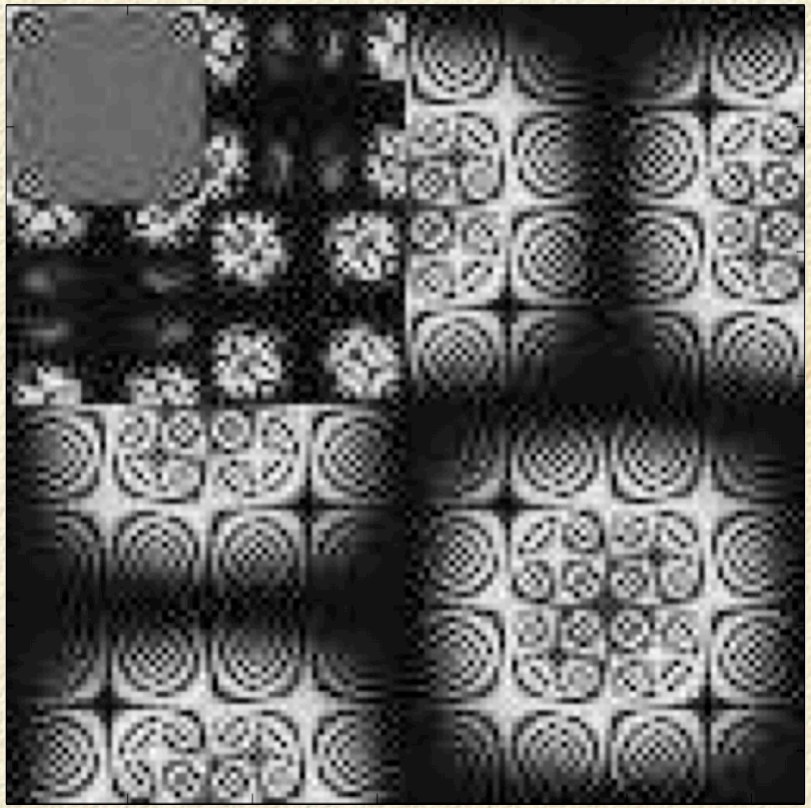
Discrete Wavelet Transform



DWT Example

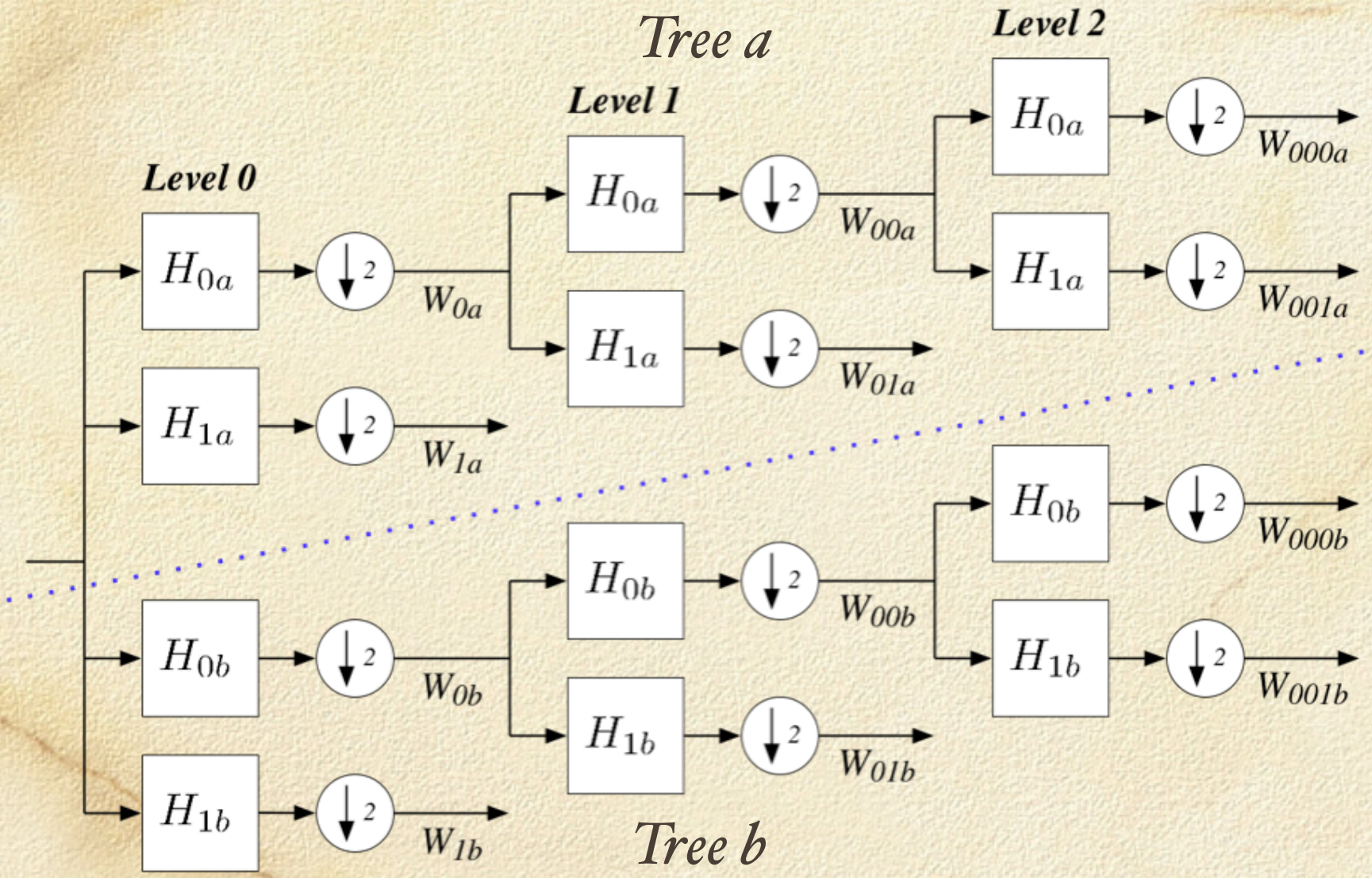


Sample image

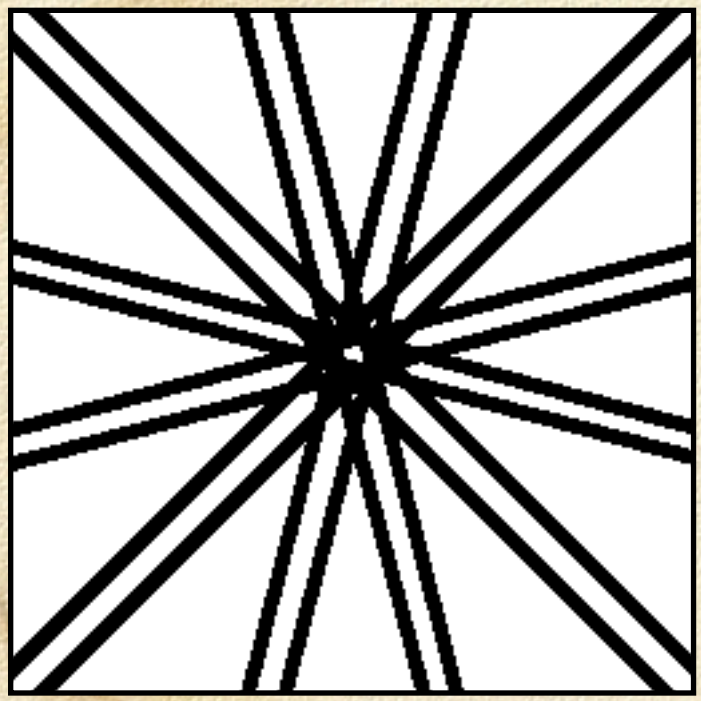


DWT

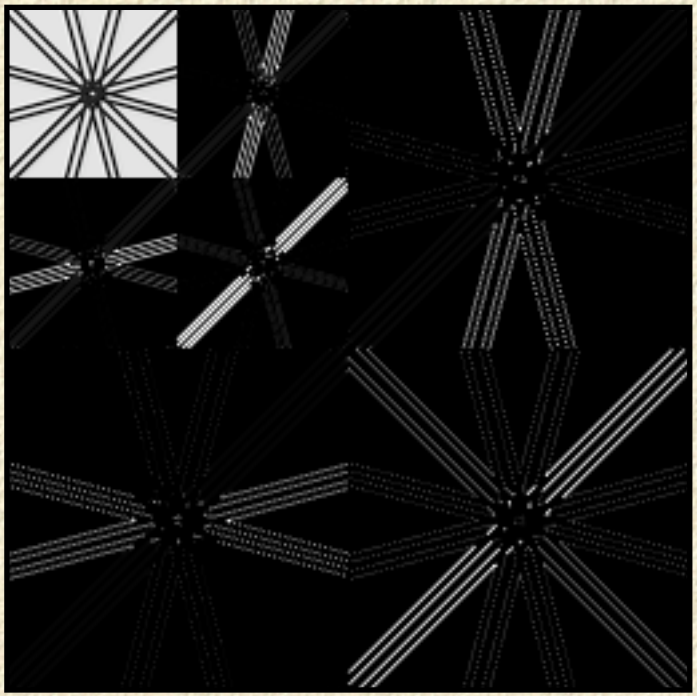
Complex Wavelet Transform



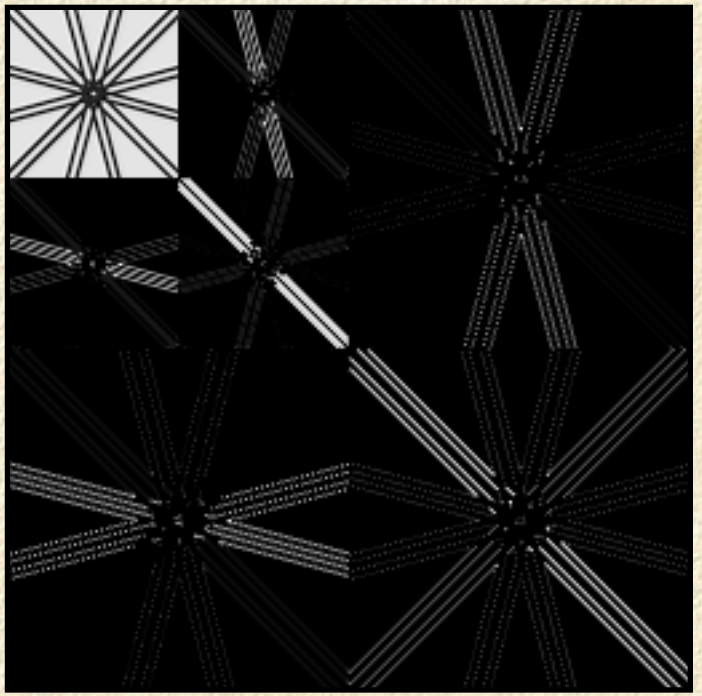
CWT Example



Sample image

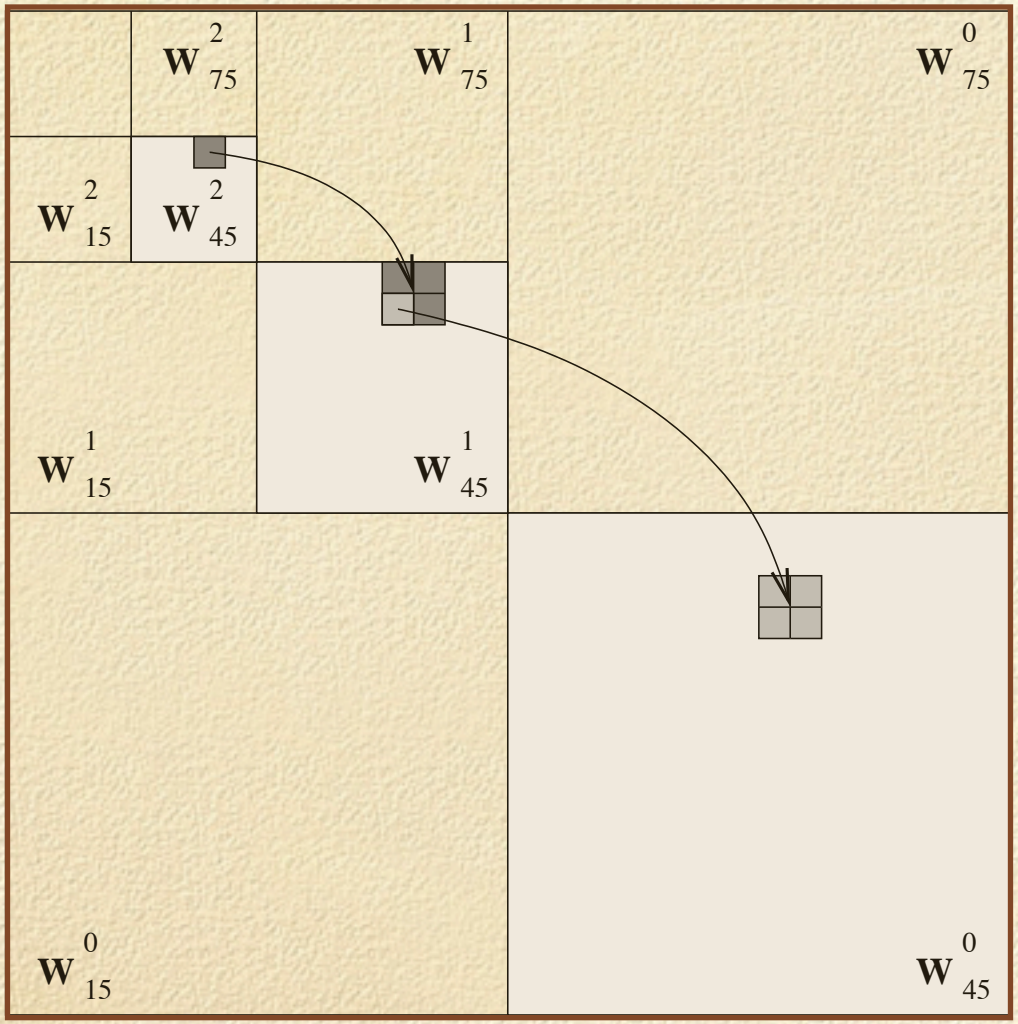


CWT-a



CWT-b

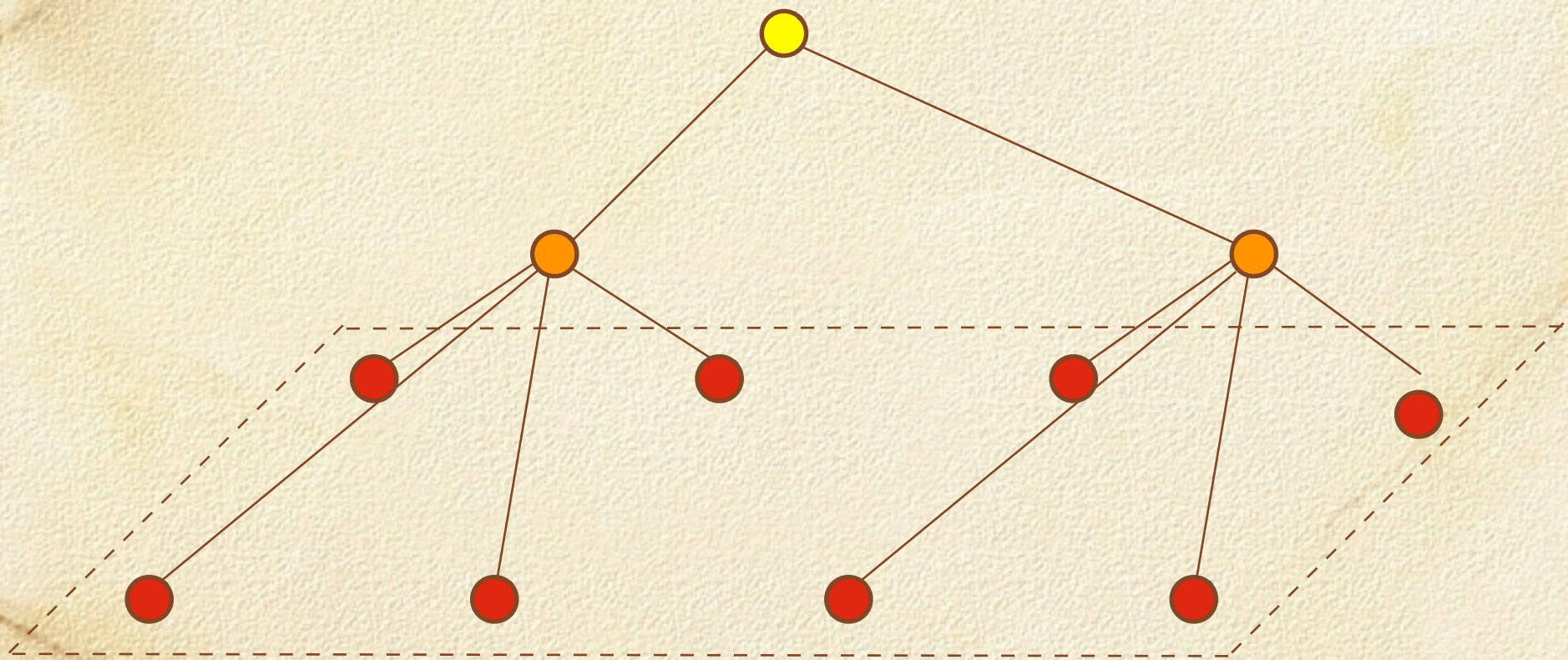
Wavelet Transform Properties



Wavelet Transform Properties

- locality
- energy compression
- decorrelation
- clustering
- persistence through scales

Building Quad-Trees from Wavelets



Shortcomings of Wavelets

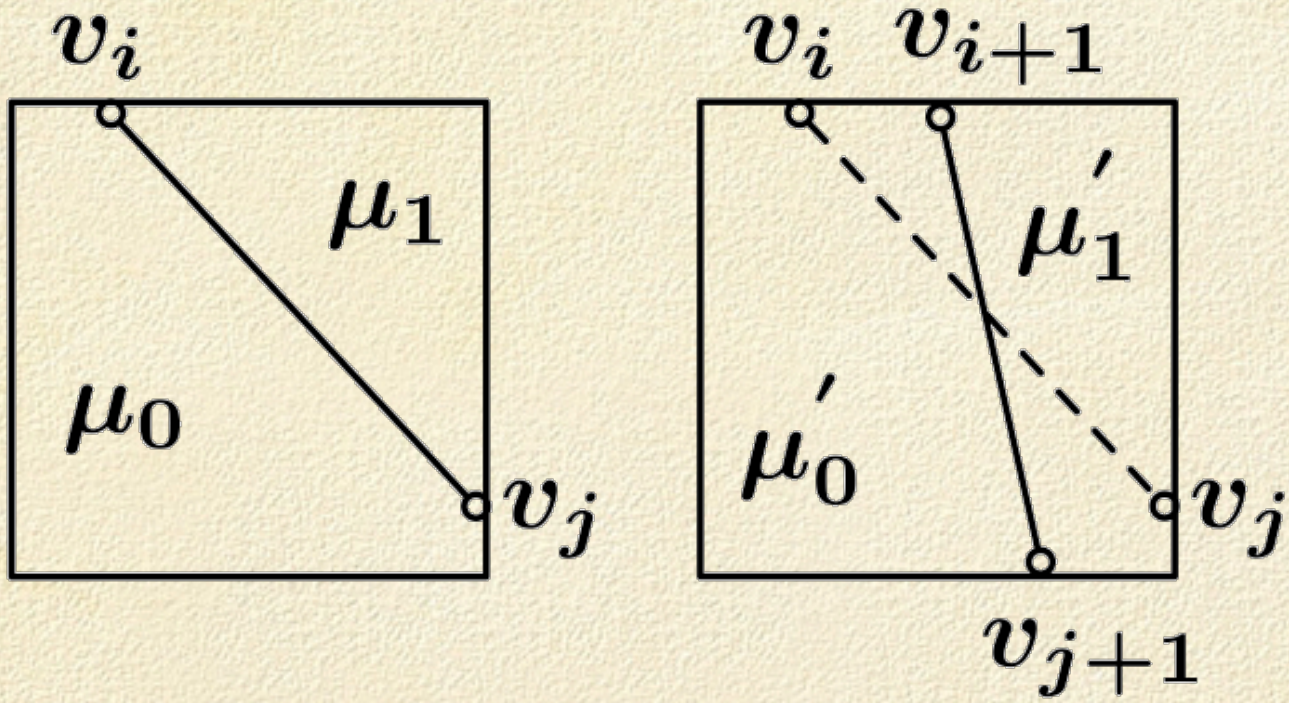
- poor orientation and elongation selectivity
- poor representation of complex structures
- clustering of wavelets with large magnitudes
- not transformation invariant
- no resilience to video noise
- no representation of color

Example of Wavelet Shortcomings

Sample image

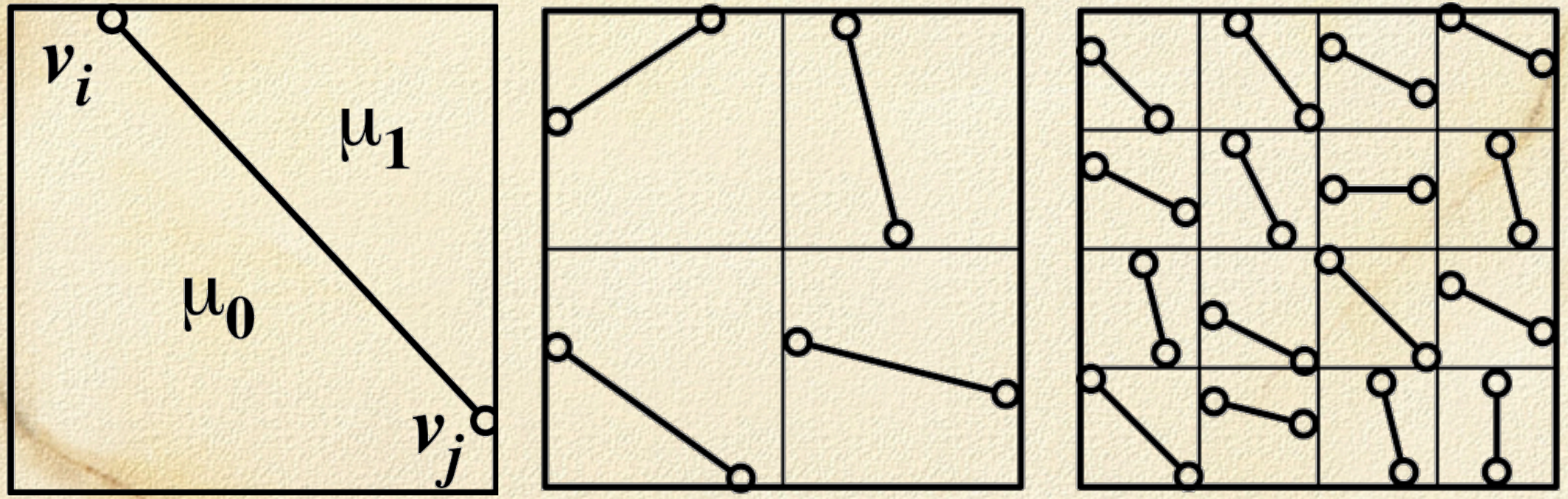
DWT

Wedgelets & Discriminant Analysis

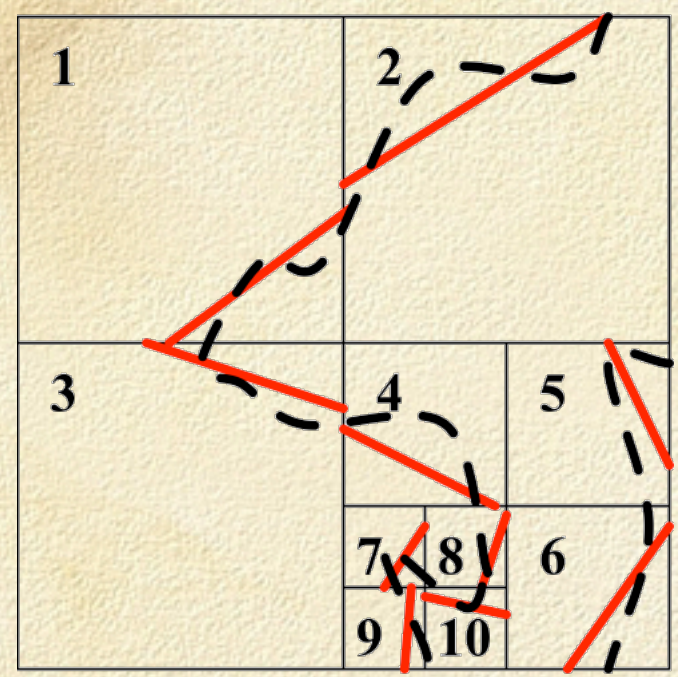


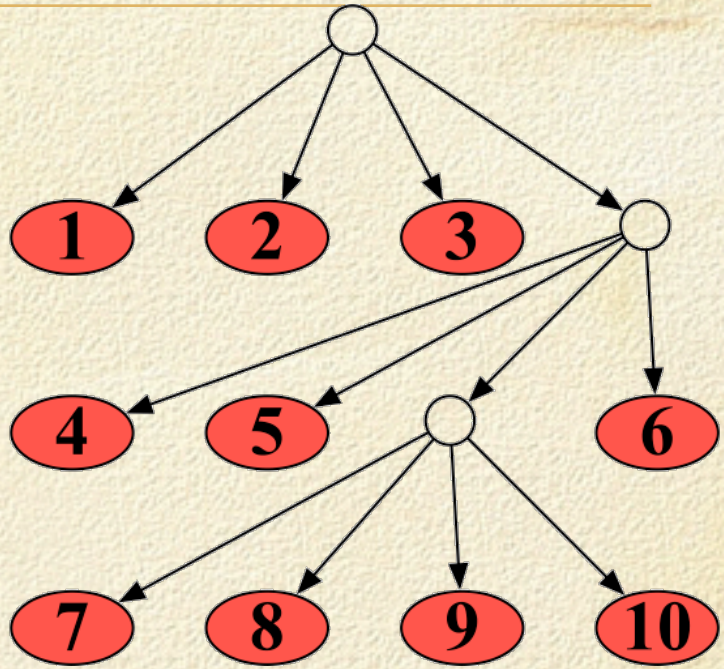
$$d = \max_{(v_i, v_j)} \{(\mu_0 - \mu 1)^T (\Sigma_0 + \Sigma_1)^{-1} (\mu_0 - \mu_1)\}$$

Multiscale Discriminant Analysis



MLDA Tree





$$g_{i,j} = |\cos 2(\angle d_i - \angle d_j)|$$

$$G_{i,pa} = |\cos 2(\angle d_i - \angle d_{pa})|$$

MLDA Example

Sample image

MLDA (1024 nodes)

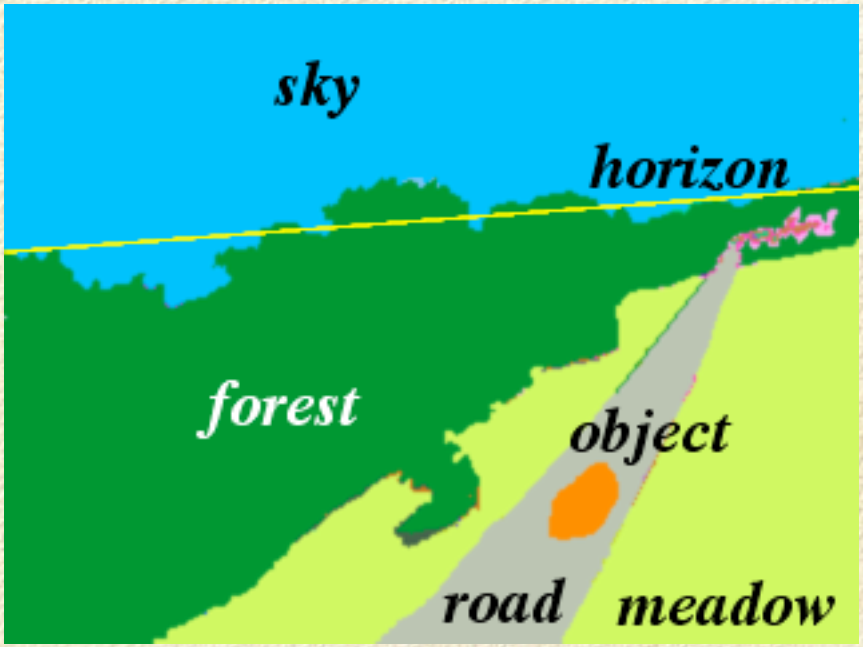
MLDA (~100 nodes)

Conclusion

Multiscale image processing is good!

Our Goal ?

Sample image



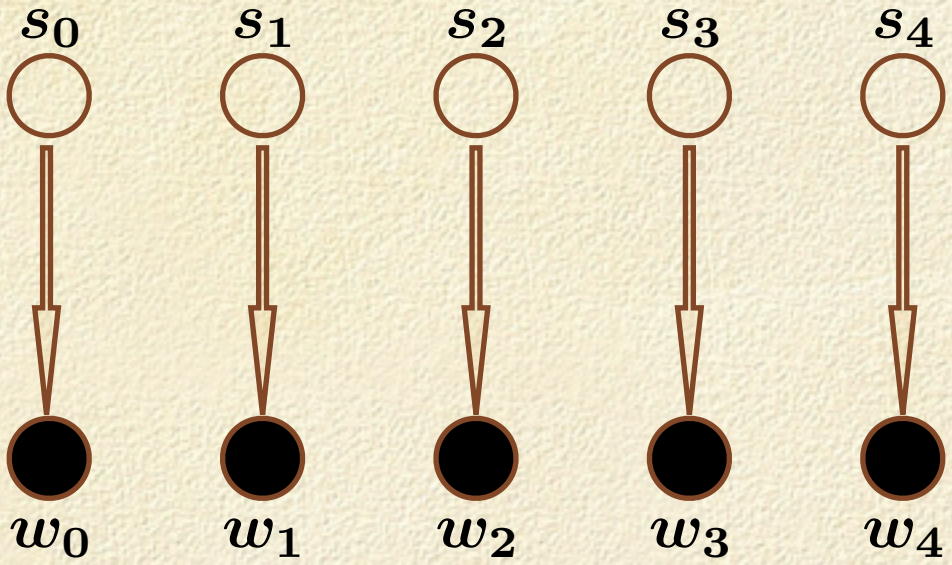
Desired output

Pixel labeling

Inherent Uncertainty

- camera quality and position
- illumination conditions
- scene diversity
- randomness of object clutter and occlusion
- video noise

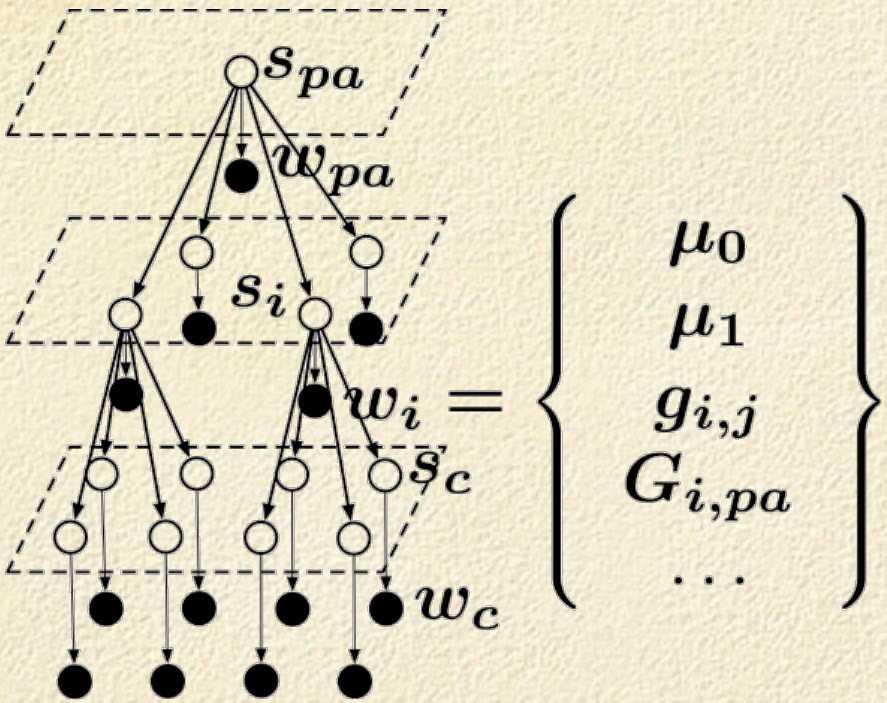
What is Pixel Labeling ?



$$\max_{s_i}\{P(s_i|w_i)\} = \max_{s_i}\{P(s_i,w_i)\} = \max_{s_i}\{P(w_i|s_i)P(s_i)\}$$

$$\max_{S}\{P(W|S)P(S)\} = \max_{S}\{\prod_{i} P(w_i|s_i)P(S)\}$$

Hidden Markov Trees



$$P(S) = P(s_i, s_{pa(i)}, s_{gpa(i)}, \ldots, s_j, s_{pa(j)}, \ldots)$$

$$= P(s_i|s_{pa(i)})P(s_j|s_{pa(j)})P(s_{pa(i)}, s_{gpa(i)}, \ldots, s_{pa(j)}, \ldots)$$

$$= \prod_i \prod_J P(s_i^J | s_{pa(i)}^{J+1})$$

How to Compute $P(w_i|s_i)$?

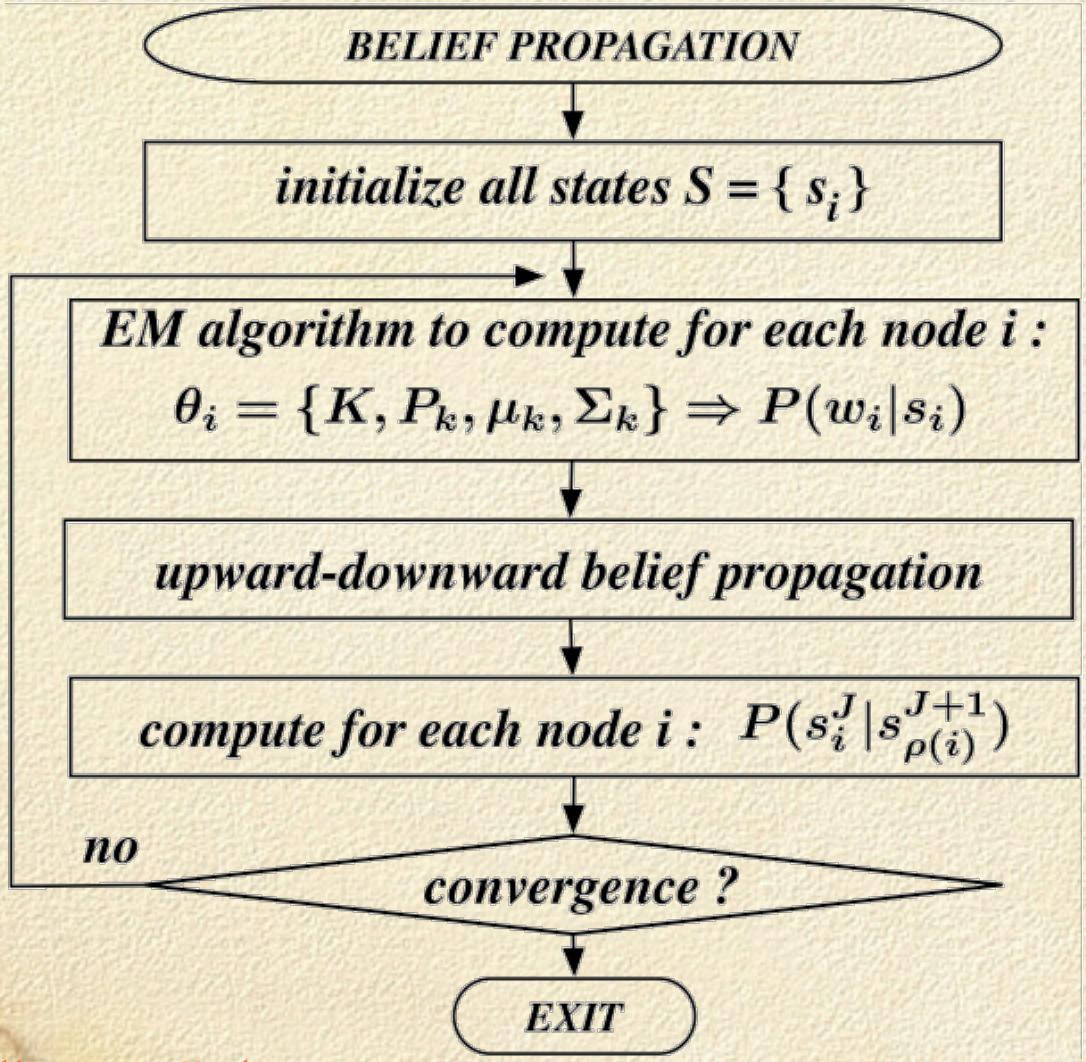
$$P(w_i|s_i) = \sum_k N(w_i, \mu_k, \Sigma_k) P_k$$

$$N(w_i, \mu_k, \Sigma_k) = \frac{1}{(2\pi)^{\frac{d}{2}} |\Sigma_k|^{\frac{1}{2}}} \exp(-\frac{1}{2}(w_i - \mu_k)^T \Sigma_k^{-1} (w_i - \mu_k))$$

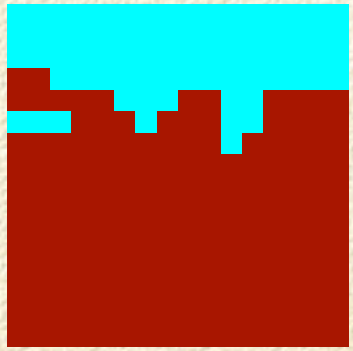
EM algorithm computes:

$$\theta_i = \{K, P_k, \mu_k, \Sigma_k\}$$

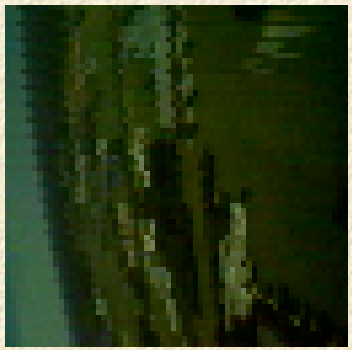
How to Compute $P(s_i^J | s_{\rho(i)}^{J+1})$?



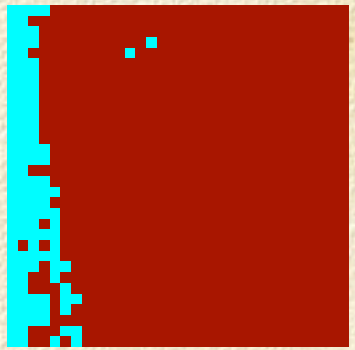
Wavelet-based Sky/Ground Recognition



image



subsampled



segmentation

MLDA-based Image Interpretation

image

MLDA

segmentation

image

MLDA

artificial structure