POLARIMETRIC SAR CLASSIFICATION

Dr. A. Bhattacharya
(Slide courtesy Prof. E. Pottier and Prof. L. Ferro-Famil)
WISHART PDF

\[ P\left(\frac{[T]}{[T_m]}\right) = \frac{L^{L_p} \left|[T]\right|^{L_p-1} e^{-LT_T^{-1} [T] [T]^\dagger [T]}}{\pi^{\frac{p(p-1)}{2}} \Gamma(L) \cdots \Gamma(L-p+1) \left| [T_m] \right|^L} \]

SUPERVISED POLSAR CLASSIFICATION

J.S LEE, M.R GRUNES, E.POTTIER (2002)
WISHART CLASSIFIER

Target Vector

\[ X = \begin{bmatrix} S_{\text{III}} & \sqrt{2}S_{\text{HV}} & S_{\text{VV}} \end{bmatrix}^T \]

\[ P(X) = \frac{1}{\pi^3|c|} e^{-X^*T[c]^{-1}X} \]

\[ k = \frac{1}{\sqrt{2}} \begin{bmatrix} S_{\text{HH}} + S_{\text{VV}} & S_{\text{HH}} - S_{\text{VV}} & 2S_{\text{HV}} \end{bmatrix}^T \]

\[ P(k) = \frac{1}{\pi^3|T|} e^{-k^*T[T]^{-1}k} \]

Coherency Matrix

\[ \langle [T] \rangle = \frac{1}{N} \sum_{i=1}^{N} k_i \cdot k_i^* \]

\[ = \frac{1}{N} \sum_{i=1}^{N} [T_i] \]

\[ P(\langle [T] \rangle / [T_m]) = \frac{L^p \langle [T] \rangle^{L-p} e^{-LTr([T_m]^{-1}\langle [T] \rangle)}}{\frac{p(p-1)}{2} \pi^2 \Gamma(L)\ldots\Gamma(L-p+1)[T_m]^L} \]

COMPLEX WISHART DISTRIBUTION

L: Number of Look  p: Polarimetric Dimension
WISHART CLASSIFIER

 Courtesy of Dr J.S Lee

\[ 2A_0 \quad B_0 + B \quad B_0 - B \]

JPL AIRSAR
P-L-C Band Flevoland Data

Original Ground-Truth

Training Sets / Reference map
Courtesy of Dr J.S Lee

$2A_0$  $B_0 + B$  $B_0 - B$

JPL AIRSAR
L-Band Flevoland Data

C-band (66.53%)
Courtesy of Dr. J.S. Lee

2A₀  \( B₀ + B \)  \( B₀ - B \)

JPL AIRSAR
L-Band Flevoland Data

L-band (81.63%)
$2A_0 \quad B_0 + B \quad B_0 - B$

JPL AIRSAR
L-Band Flevoland Data

Courtesy of Dr J.S Lee

P-band (71.37%)
2A_o  \quad B_0 + B  \quad B_0 - B

JPL AIRSAR
L-Band Flevoland Data

P-L-C band (91.21%)
WISHART PDF

\[ P((T)/[T_m]) = \frac{L^Lp([T])^{L-p} e^{-Ltr([T_m]^{-1}[T])}}{\pi^{p(p-1)/2} \Gamma(L)\ldots\Gamma(L-p+1)[T_m]^L} \]

SUPERVISED
POLSAR
CLASSIFICATION

J.S LEE, M.R GRUNES, E.POTTIER (2002)

Quantitative Comparison
Fully Polarimetric versus Dual Polarizations
Courtesy of Dr. J.S. Lee

L-band Fully Pol. (81.63%)

L-band complex HH and VV (80.91%)

L-band HH and VV Intensities (56.35%)

Reference map for comparison
# Supervised Classifier

*Courtesy of Dr J.S Lee*

<table>
<thead>
<tr>
<th></th>
<th>Fully Polarimetric</th>
<th>Complex HH, HV</th>
<th>Intensity HH, HV</th>
<th>Complex HH, VV</th>
<th>Intensity HH, VV</th>
<th>Complex VV, HV</th>
<th>Intensity VV, HV</th>
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<tbody>
<tr>
<td>Stem Bean</td>
<td>95.32</td>
<td>51.16</td>
<td>63.27</td>
<td>90.64</td>
<td>61.73</td>
<td>35.97</td>
<td>31.29</td>
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<td>Forest</td>
<td>81.07</td>
<td>66.73</td>
<td>68.39</td>
<td>75.75</td>
<td>33.83</td>
<td>60.05</td>
<td>60.91</td>
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<td>Potatoes</td>
<td>82.89</td>
<td>67.53</td>
<td>66.36</td>
<td>81.52</td>
<td>49.35</td>
<td>54.40</td>
<td>59.15</td>
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<tr>
<td>Lucerne</td>
<td>97.91</td>
<td>39.29</td>
<td>38.23</td>
<td>99.26</td>
<td>65.15</td>
<td>67.49</td>
<td>65.30</td>
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<tr>
<td>Wheat</td>
<td>64.80</td>
<td>49.77</td>
<td>44.27</td>
<td>68.02</td>
<td>53.72</td>
<td>49.43</td>
<td>41.65</td>
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<tr>
<td>Bare Soil</td>
<td>99.36</td>
<td>90.04</td>
<td>82.86</td>
<td>98.42</td>
<td>93.15</td>
<td>90.93</td>
<td>63.74</td>
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<tr>
<td>Beet</td>
<td>89.26</td>
<td>68.80</td>
<td>66.36</td>
<td>86.22</td>
<td>81.98</td>
<td>75.94</td>
<td>74.77</td>
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<td>Rape Seed</td>
<td>89.05</td>
<td>55.01</td>
<td>53.23</td>
<td>87.18</td>
<td>49.85</td>
<td>82.31</td>
<td>77.12</td>
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<td>Peas</td>
<td>86.47</td>
<td>50.77</td>
<td>39.25</td>
<td>84.59</td>
<td>65.21</td>
<td>81.82</td>
<td>79.59</td>
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<td>Grass</td>
<td>91.05</td>
<td>66.44</td>
<td>65.06</td>
<td>90.13</td>
<td>71.08</td>
<td>75.36</td>
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<tr>
<td>Water</td>
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<td>90.39</td>
<td>87.33</td>
<td>100</td>
<td>99.86</td>
<td>96.30</td>
<td>70.53</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>81.63</strong></td>
<td><strong>59.16</strong></td>
<td><strong>55.38</strong></td>
<td><strong>80.91</strong></td>
<td><strong>56.35</strong></td>
<td><strong>64.72</strong></td>
<td><strong>60.12</strong></td>
</tr>
</tbody>
</table>
SUPERVISED CLASSIFIER

For crop classification
- L-band is better than P-Band and C-band
- Dual-pol HH and VV with coherence (Including phase differences) is almost as good as fully polarimetric

For forest classification
- P-band is better than L and C
- HV is the most important polarization
- Coherence is not important for classification
WISHART PDF

\[
P([T]/[T_m]) = \frac{L^p [T]^{L-p} e^{-\text{Tr}([T_m]^{-1}[T])}}{\pi^{\frac{L}{2}} \Gamma(L) \ldots \Gamma(L-p+1)[T_m]^{L}}
\]

UNSUPERVISED POLSAR CLASSIFICATION

E. POTTIER, J. S. LEE (2000)

H / A / \alpha DECOMPOSITION THEOREM
H / $\alpha$ CLASSIFICATION

H-\(\alpha\) classification

\[\text{H / } \alpha\text{ Classification Space}
\]

Sub-divided into 9 basic zones

Location of the boundaries is arbitrary and generically

Degree of arbitrariness on the setting of these boundaries

Segmentation is offered merely to illustrate the unsupervised classification strategy and to emphasize the geometrical segmentation of physical scattering processes
H / $\alpha$ - WISHART CLASSIFIER

1994  *LEE et al.* PROPOSED A SUPERVISED ALGORITHM BASED ON THE COMPLEX WISHART DISTRIBUTION FOR THE COMPLEX COVARIANCE / COHERENCY MATRIX.

1998  *LEE et al.* DEVELOPED A COMBINED UNSUPERVISED CLASSIFICATION METHOD THAT USES THE H / $\alpha$ PLANE WHICH INITIALLY CLASSIFIES THE POLSAR IMAGE. THIS SEGMENTED IMAGE IS THEN USED AS TRAINING SETS FOR THE INITIALIZATION OF THE SUPERVISED WISHART CLASSIFIER.

1999  INTRODUCTION OF THE ANISOTROPY (*E. POTTIER - J.S.LEE*) IMPROVEMENT OF THE CAPABILITY TO DISTINGUISH BETWEEN DIFFERENT CLASSES WHOSE CENTERS END IN THE SAME ENTROPY (H) AND ALPHA ($\alpha$) ZONE.
k - mean CLASSIFICATION PROCEDURE

- PROVIDE INITIAL \([T_m]^{(0)}\) FOR EACH CLASS
- CLASSIFY THE WHOLE IMAGE WITH THE DISTANCE PROCEDURE
  \(\langle T \rangle \in [T_m] \text{ if } d_m(\langle T \rangle) < d_j(\langle T \rangle) \forall j \neq m\)
- COMPUTE \([T_m]^{(k+1)}\) FOR EACH CLASS USING THE CLASSIFIED PIXELS OF STEP 2
  \([T_m]^{(k+1)} = \frac{1}{N_m} \sum_{j=1}^{N_m} \langle T \rangle_j\)
- TERMINAISON CRITERION?

Cluster Center of the class \(m\) (Lee 1998)
H / α - WISHART CLASSIFIER

During the classification, the cluster centers can move out of their zones or several clusters may end in the same zone.

Identification of the terrain type may cause some confusion due to the color scheme.

The combined Wishart classifier is extended and complemented with the introduction of the Anisotropy (A).
H / A / $\alpha$ - WISHART CLASSIFIER

POLSAR DATA DISTRIBUTION IN THE H / A / $\alpha$ SPACE
$2A_0$  $B_0 + B$  $B_0 - B$
H / $\alpha$ and WISHART CLASSIFIER

H / A / $\alpha$ and WISHART CLASSIFIER
- Polarimetric SAR (POLSAR) classification
  - Complex Wishart distribution (Lee et al., 1994)
  - Wishart + Entropy/Alpha (Lee et al., 1999)
  - Wishart + Entropy/Alpha/Anisotropy (Pottier and Lee, 2000)
  - Deficiency: Wishart classifier is a statistic operator. Pixels in a class can be mixed in scattering mechanisms

- A new approach
  - Preserving scattering property of each pixel based on Freeman and Durden decomposition:
    - Double bounce
    - Surface
    - Volume (Canopy)
  - Better stability in convergence
  - Automated color rendering