METU

EVALUATION OF TEXTURAL FEATURES FOR MULTISPECTRAL IMAGES

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Outline

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- Motivation & Aim
- Dataset
- Workflow
- Traditional/Popular Textural Features
- Recent Textural Approaches
- Feature Comparison Approaches
- Evaluation of Features
- Conclusion

Motivation & Aim

- Land Use – Land Cover (LULC) Classification
  - USGS LULC class hierarchy (Anderson's)
  - Problems:
    - High within-class variance
    - Resolution
    - Reflectance characteristics of satellites
- Various approaches proposed
  - Success to key: Distinctive features with appropriate distance metric
- Aim: determining representative features for each class

	Level I		Level II
1	Urban or built-up land	1.1	Residential
		1.2	Commercial & services
		1.3	Industrial
		1.4	Transportation, communications & utilities
		1.5	Industrial & commercial complexes
		1.6	Mixed urban or built-up land
		1.7	Other urban or built-up land
2	Agricultural land	2.1	Cropland & pasture
		2.2	Orchards, groves, vineyards, nurseries & ornamental horticultural areas
		2.3	Confined feeding operations
		2.4	Other agricultural land
4	Forest land	4.1	Deciduous forest land
		4.2	Evergreen forest land
		4.3	Mixed forest land
5	Water	5.1	Streams & canals
		5.2	Lakes
		5.3	Reservoirs
		5.4	Bays & estuaries
3,6-9	...	...	

Table 1. USGS LULC class hierarchy

Dataset

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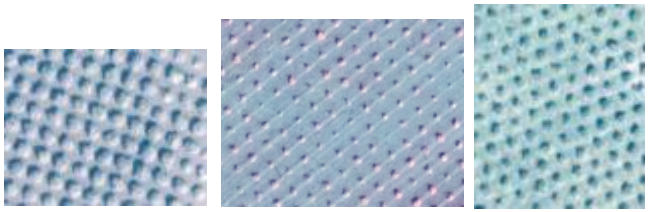
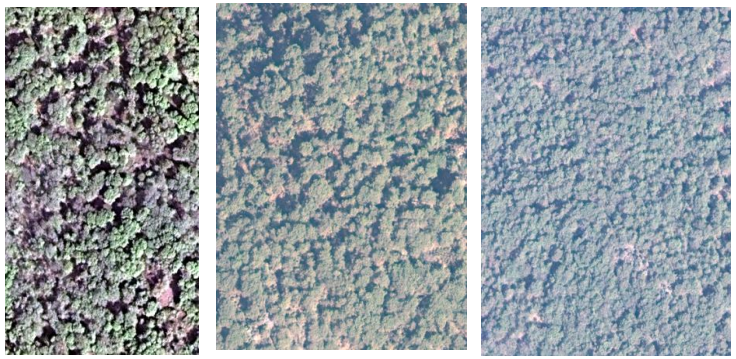
- High resolution (0.6 m) Quickbird data of Fethiye, Turkey

Urban samples



Cropland samples



Forest samples

Water sample

Class	# train patches	# test patches
Water	50	50
Forest	50	77
Urban	50	32
Crop	50	46

Table2. Number of samples in dataset

Workflow

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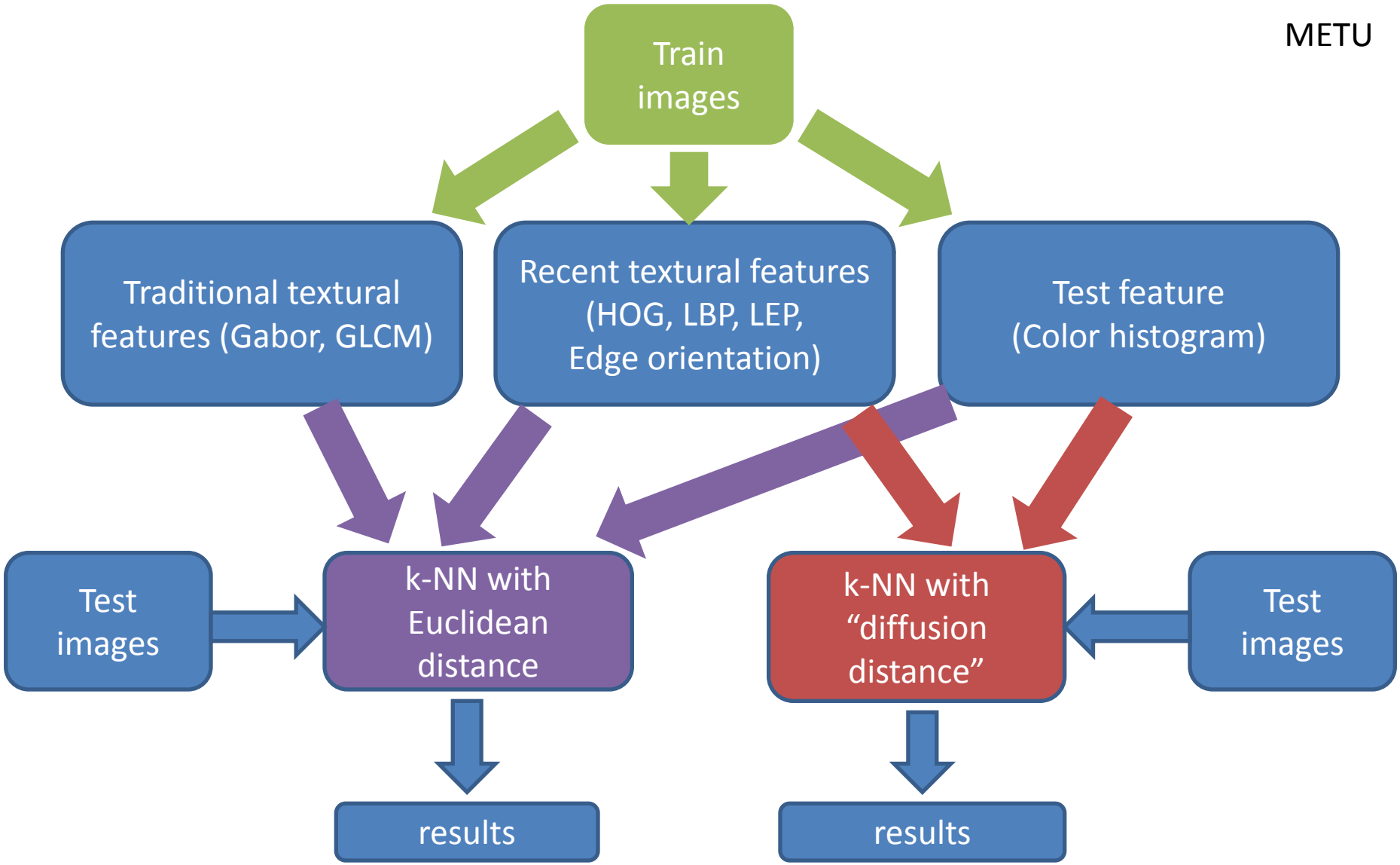

Traditional Textural Features

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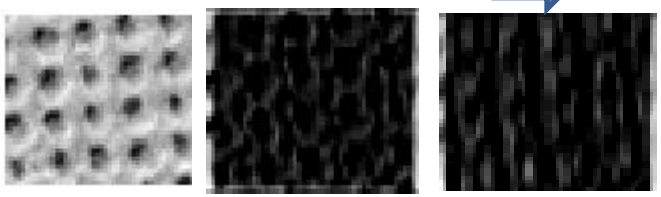
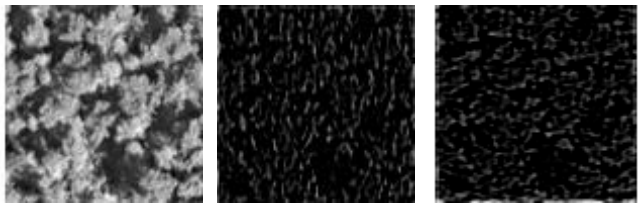
- Filtering-based features
  - Wavelet based
  - Gabor based → mean & std_dev of response



a) b) c)

Figure 1. a) Red band of crop sample
b) Gabor response at 0° and scale = 1
c) Gabor response at 0° and scale = 4



a) b) c)

Figure 2. a) Red band of forest sample
b) Gabor response at 0° and scale = 1
c) Gabor response at 90° and scale = 1

- Gray-level co-occurrence matrix (GLCM) features
  - Contrast ("**sum of squares variance**")
  - Energy (**"square root of ASM"**)
  - Homogeneity (**"Inverse Difference Moment"**)

Recent Textural Approaches

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- Histogram of Oriented Gradients (HOG)
- Local Binary Pattern (LBP)
  - LBPV (LBP with local variance)
    - Uniform
    - Rotation Invariant
    - Rotation Invariant - Uniform
- Local Edge Pattern (LEP)
- Edge Orientation
  - Steerable filter applied beforehand

Robust to illumination change as pattern is unchanged

Edge sensitive

Histogram of Oriented Gradients (HOG)

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- Accumulated histograms with 9 bins (range of 20 degrees per bin)

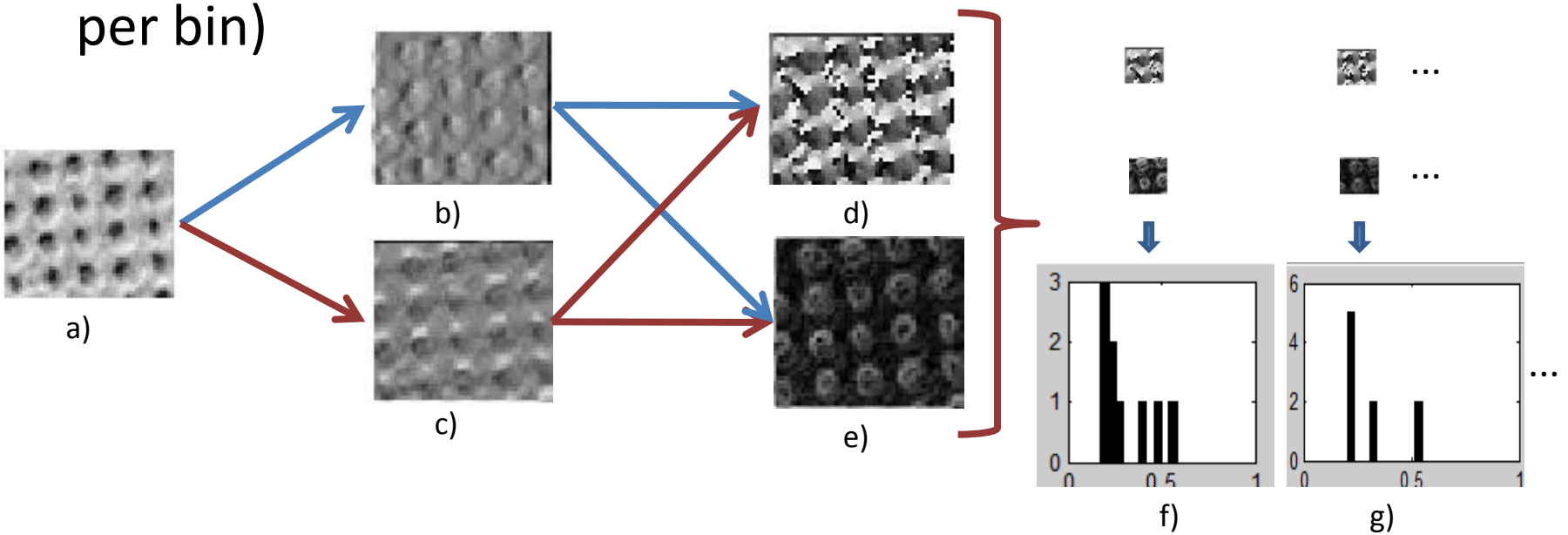

Figure 3. a) Red band of crop sample b) Gradient filter response in x direction c) Gradient filter response in y direction d) Magnitude image from gradient responses e) Angle image from gradient responses f-g) Histograms of each window

- Reported to be robust according to Haar-like features for car detection in remotely-sensed data [1]

1.Tuermer, S., Leitloff, J., Reinartz, P. and Stilla, U., "Evaluation of selected features for car detection in aerial images," ISPRS Hannover Workshop, High-Resolution Earth Imaging for Geospatial Information, (2011)

Local Binary Pattern (LBP)

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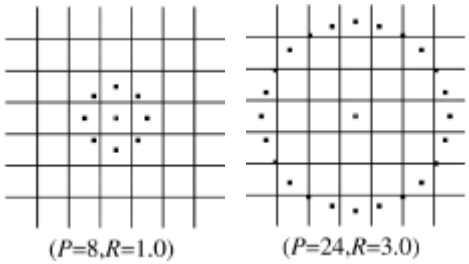
- Local Binary Pattern (LBP)
  - Uniform
  - Rotation Invariant
  - Rotation Invariant - Uniform



$$s(x) = \begin{cases} 1, x \geq 0 \\ 0, x < 0 \end{cases}$$

$$LBP_{P,R} = \sum_{p=0}^{P-1} s(g_p - g_c)2^p$$

  - Multi-resolution approach (with 8- & 24-neighbors)
    - Distance = $\text{Distance}_8 + \text{Distance}_{24}$

- LBPV (LBP with local variance)
  - No need for quantization according to LBP/VAR

Local Edge Pattern (LEP)

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- Local Edge Pattern (LEP)
  - Rotation invariant case in 8 neighborhood
  - # of patterns duplicate due to central pixel's being on/off
  - Canny edge detector applied beforehand

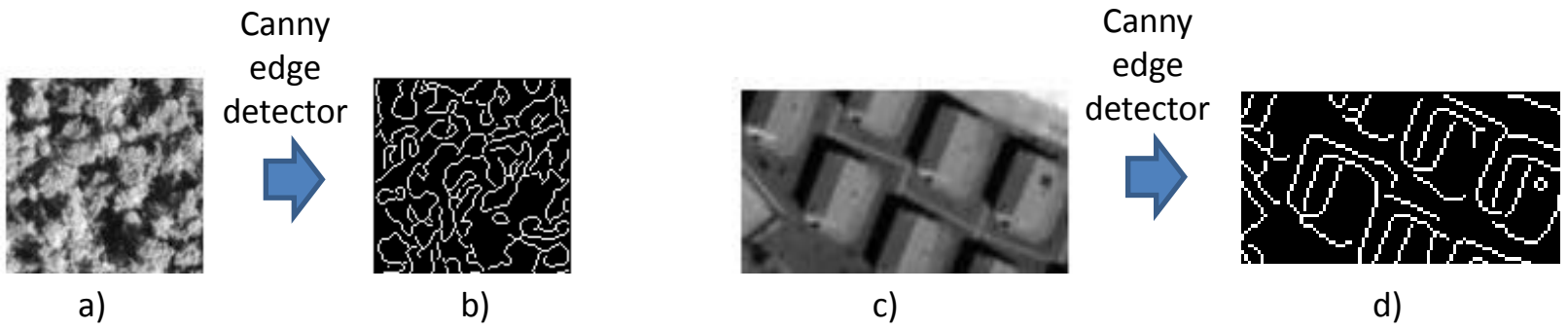

Figure 4. a) Red band of forest sample b) Edge image of a). c) Red band of urban sample d) Edge image of c)

Edge Orientation

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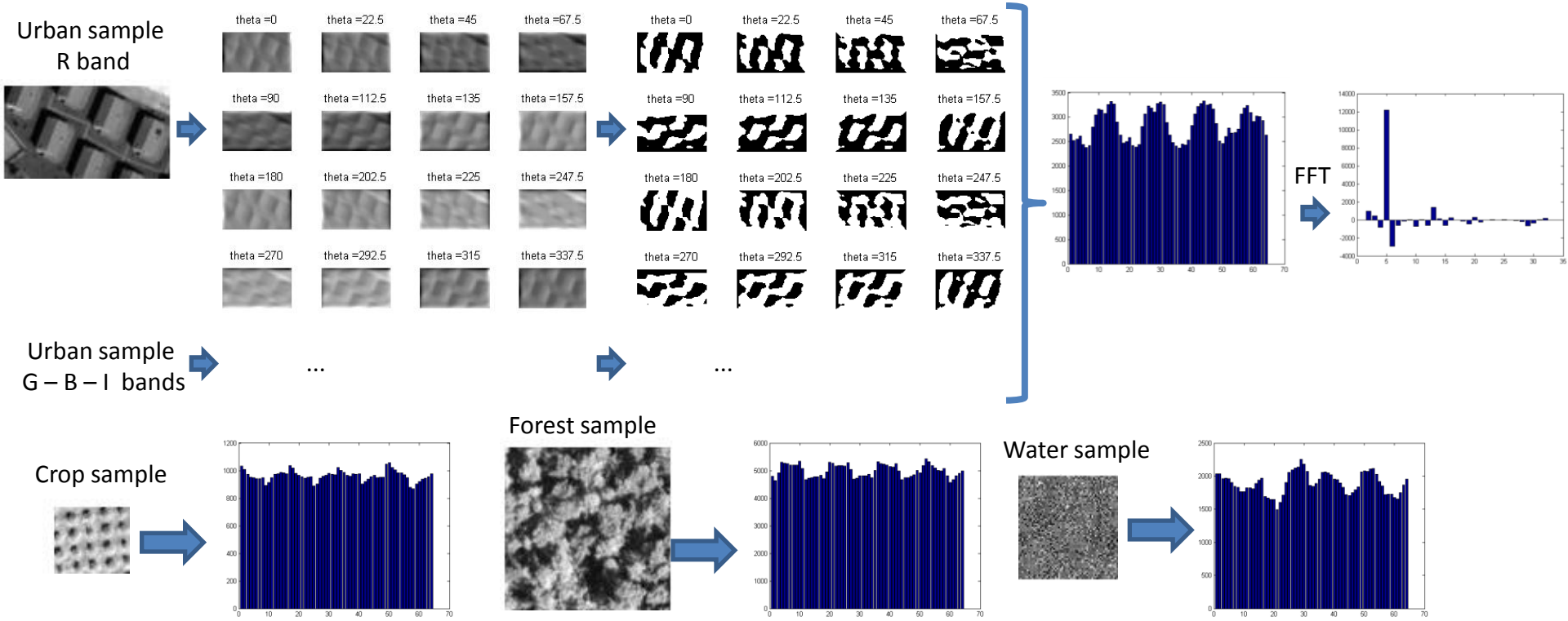
- Edge Orientation
  - Steerable filter applied in 16 directions beforehand
  - Histograms of 4 bands adjoined ➡ 64-bin histogram



Feature Comparison Approaches

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- Bin-to-bin comparison with Euclidean distance:

$$d(h_1, h_2) = \sqrt{(h_1(1) - h_2(1))^2 + (h_1(2) - h_2(2))^2 + \ldots + (h_1(n) - h_2(n))^2} = \sqrt{\sum_{k=1}^{n} (h_1(k) - h_2(k))^2}$$

  - Problems reported [2]:
    - Sensitive to quantization effects
    - Sensitive to distortion problems due to deformation, illumination change and noise
  - cross-bin distance metric required
- "Diffusion Distance" metric:

$$\widehat{K}(h_1, h_2) = \int_0^{\bar{t}} k(|T(x,t)|)dt$$

  - k norm m ıation between two histograms
  - Alternative to Kullback-Leibler (KL) distance
- k-nearest neighbor approach (k-NN) for classification with both metrics

2. Ling, H. and Okada, K., "Diffusion distance for histogram comparison," Computer Vision and Pattern Recognition, 2006 IEEE Computer Society Conference, vol.1, 246-253 (2006).

Evaluation of Features

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- Evaluation of LBP-variant features within themselves
- Evaluation of all features compared to color histogram feature as a test feature
- Evaluation of comparison metrics
  - Classic k-NN with Euclidean distance over each dimension of features
  - k-NN with histogram-based diffusion distance where applicable

Evaluation of LBP-variant features

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Table 3. LBP and LEP feature results classified according to diffusion distance

Features\Accuracies	Water (%)	Forest (%)	Urban (%)	Crop (%)	Overall (%)
LBP-V Uniform	100	98,7	100	89,13	**98,54**
LBP-V Rot. Inv.	100	90,90	100	97,83	98,05
LBP-V Rot. Inv. Uniform	100	89,61	100	100	98,05
LBP Uniform	100	100	87,50	100	**99,02**
LBP Rot. Inv.	100	90,90	100	97,83	98,05
LBP Rot. Inv. Uniform	100	89,61	100	100	98,05
LEP Rot. Inv. (8-neighborhood)	97,83	71,43	96,87	84,78	91,46

- LBP & LBPV not much different with diffusion distance metric
- Uniform case to be preferred with diffusion distance

Table 4. LBP and LEP feature results classified according to bin-by-bin comparison (Euclidean distance)

Features\Accuracies	Water(%)	Forest(%)	Urban(%)	Crop(%)	Overall (%)
LBP-V Uniform	98	96,10	96,87	80,43	96,59
LBP-V Rot. Inv.	100	100	93,75	95,65	**99,02**
LBP-V Rot. Inv. Uniform	98	97,40	96,87	67,39	95,37
LBP Uniform	100	93,51	93,75	100	98,29
LBP Rot. Inv.	100	100	100	97,82	**99,76**
LBP Rot. Inv. Uniform	100	96,10	100	100	**99,27**
LEP Rot. Inv. (8-neighborhood)	90	72,72	96,87	84,78	91,71

- LEP not recommended for forest class in both distance cases
- Rotation Inv. case superior with bin-by-bin comparison

Evaluation of all features with Euclidean distance metric

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Table 5. All features classified according to Euclidean distance

Features\Accuracies	Water(%)	Forest(%)	Urban(%)	Crop(%)	Overall (%)
GLCM	98	94,80	96,87	76,09	95,85
Gabor	100	100	100	97,82	**99,76**
HOG	100	100	68,75	84,78	95,85
LBP Rot. Inv.	100	100	100	97,82	**99,76**
LEP	90	72,72	96,87	84,78	91,71
Edge Orientation	76	72,72	93,75	91,30	90,49
Color Histogram	94	96,10	100	93,48	97,80

- Gabor and LBP Rot. Inv. superior according to others with bin-to-bin comparison
- Color histogram competitive, yet inadequate as dataset grows
- Poor performance with GLCM for crop class, with HOG for urban class, with LEP or edge orientation for forest class

Evaluation of all features with diffusion distance metric

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Table 6. All histogram features classified according to diffusion distance

Features\Accuracies	Water(%)	Forest(%)	Urban(%)	Crop(%)	Overall (%)
HOG	100	100	68,75	84,78	96,83
LBP Uniform	100	100	87,50	100	**99,02**
LEP	90	71,43	96,87	84,78	91,46
Edge Orientation	74	88,31	93,75	86,95	92,68
Color Histogram	100	96,10	100	100	**99,27**

- LBP Uniform case able to capture patterns well due to its multi-resolution usage
- Color histogram competitive, yet inadequate as dataset grows
- Poor performance with GLCM for crop class, with HOG for urban class, with LEP for forest class, with edge orientation for water class

Conclusion

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Table 7. Evaluation of features according to each class

Class Name	Recommended Features	Not Recommended Features
Water	Gabor, HOG, LBP-Uniform(DD), color histogram (DD)	LEP, edge orientation
Forest	Gabor, HOG, LBP-Uniform(DD), LBP-Rot. Inv. (k-NN), LBPV-Rot. Inv. (k-NN)	LEP, edge orientation
Urban	Gabor, LBP-Rot. Inv., LBPV-Rot. Inv. Uniform, LBPV-Rot. Inv. (DD), LBPV-Rot. Inv. Uniform (DD) , LEP, edge orientation	Color Histogram
Crop	Gabor, LBP-Uniform, LBP Rot. Inv. Uniform	GLCM, HOG, LEP

Thank you

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Q & A