
OBJECT-BASED IMAGE PROCESSING OF VHR IMAGERY FOR OLIVE TREE MAPPING AND INVENTORY



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Context



- ORFEO Support Programme for the use of ORFEO data
- Six Belgian contribution
- SYNOPRA: Synergy of VHR optical and radar data for tree/forest mapping and inventory
- March 2006 – January 2009

Aim



- SYNOPRA aims at
 - Innovative methodological techniques
 - Exploiting synergy VHR optical and radar data
 - Tree related applications

Data / Study area



■ Data

- ❑ Optical: ADS40, 50 cm, 5 bands, May 2003
- ❑ Radar: RAMSES, 1m, X-band, interferometric, February 2003

■ Study area

- ❑ Les Baux de Provence, France
- ❑ Patchy landscape: olive and wine yards

Data / Study area



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Objectives



- Project objectives
 - Olive tree mapping
 - Olive tree inventory

Items of this talk



1. Noise removal
 - › Artificial neural network denoising technique
2. Olive orchard delineation
 - › Wavelet-based segmentation technique
3. Olive orchard stand density estimation
 - › Wavelet-based regression technique

Items of this talk



1. Noise removal
 - › Artificial neural network denoising technique
2. Olive orchard delineation
 - › Wavelet-based segmentation technique
3. Olive orchard stand density estimation
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1. Noise removal



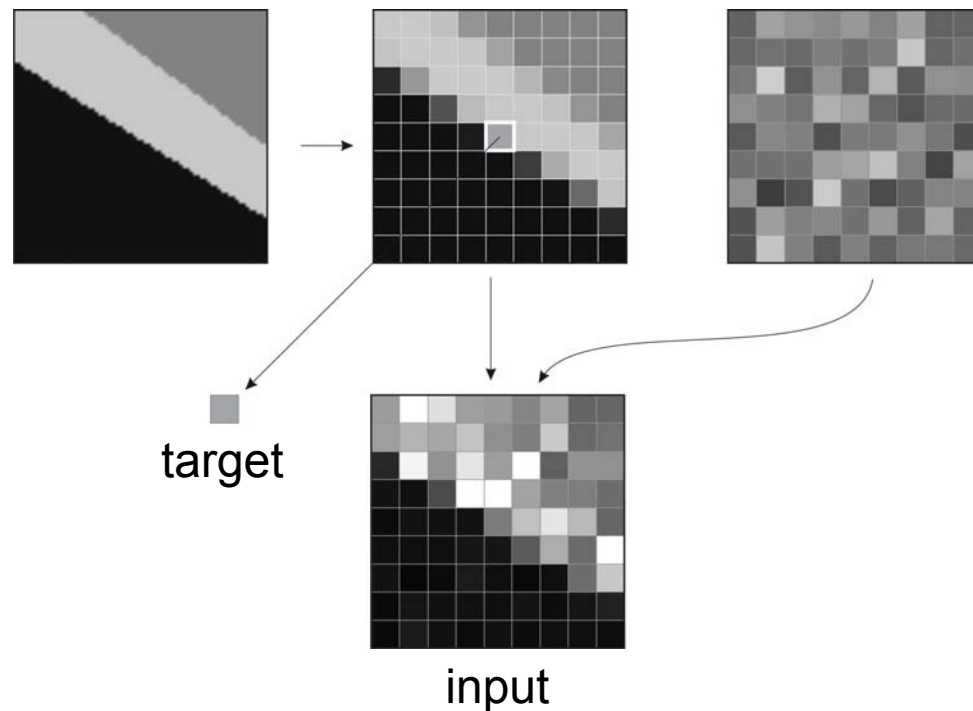
- Shortcomings classical denoising filters
 - ❑ Loss of edges
 - ❑ Presence of outliers
 - ❑ Loss of image detail

- New approach: concept
 - ❑ Train learning machine
 - ❑ Artificially generated input-target couples
 - ❑ Process real data

1. Noise removal



- New approach: concept
 - Artificial data generation



1. Noise removal



- New approach: concept
 - ❑ Artificial data generation
 - ❑ Huge amount of input-output couples
 - ❑ Train ANN learning machine
 - ❑ Process real data

1. Noise removal



- New approach: performance evaluation
 - Because no reference data for Ramses image
 - Artificial radar intensity image
 - Model of Ulaby et al. (1986)
 - Intensity component
 - Texture component
 - Speckle component
 - 9 land cover classes

1. Noise removal



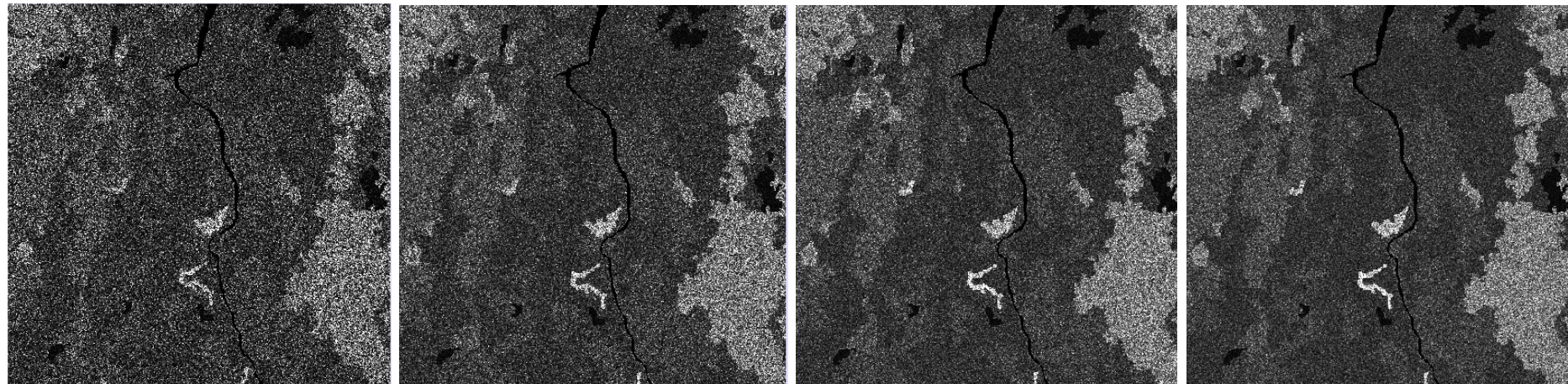
- New approach: performance evaluation
 - Artificial radar intensity image

Class	1 look		2 looks		3 looks		4 looks	
	mean	stdv	mean	stdv	mean	stdv	mean	stdv
1	0.3009	0.3116	0.2988	0.2212	0.3019	0.1865	0.3006	0.1627
2	0.9973	0.9807	1.0016	0.7518	1.0312	0.6496	1.0094	0.5356
3	0.2488	0.2593	0.2509	0.1850	0.2502	0.1526	0.2502	0.1354
4	0.1994	0.2017	0.2002	0.1441	0.2003	0.1174	0.2004	0.1026
5	0.4992	0.5006	0.5021	0.3590	0.4996	0.2933	0.4982	0.2548
6	0.1530	0.1568	0.1517	0.1105	0.1507	0.0916	0.1467	0.0725
7	0.0511	0.0522	0.0491	0.0357	0.0502	0.0305	0.0493	0.0252
8	0.7554	0.7026	0.7559	0.5409	0.7453	0.4690	0.7352	0.3950
9	0.0100	0.0106	0.0099	0.0075	0.0100	0.0061	0.0100	0.0050

1. Noise removal



- New approach: performance evaluation
 - Artificial radar intensity image



1 look

2 looks

3 looks

4 looks

1. Noise removal



■ New approach: performance evaluation

□ Noise removal

- Enhanced Frost 3x3, 5x5, 7x7
- Enhanced Lee 3x3, 5x5, 7x7
- Gamma MAP 3x3, 5x5, 7x7
- ANN 3x3, 5x5, 7x7

1. Noise removal



■ New approach: performance evaluation

□ Evaluation of denoising results

■ Image statistics

□ SNR

□ Beta

■ Class statistics

□ Relative mean difference

□ Relative CV difference

□ MSE

$$SNR = 10 \log \left(\frac{\sum_{j=1}^K R_j^2}{\sum_{j=1}^K (\hat{I}_j - R_j)^2} \right)$$

$$\beta = \frac{\Gamma(\Delta \hat{I} - \Delta \bar{I}, \Delta I - \Delta \bar{I})}{\sqrt{\Gamma(\Delta \hat{I} - \Delta \bar{I}, \Delta \hat{I} - \Delta \bar{I}) \cdot \Gamma(\Delta I - \Delta \bar{I}, \Delta I - \Delta \bar{I})}}$$

$$\Delta M_i = \frac{(\mu_{\hat{I}_i} - \mu_{R_i})}{\mu_{R_i}}$$

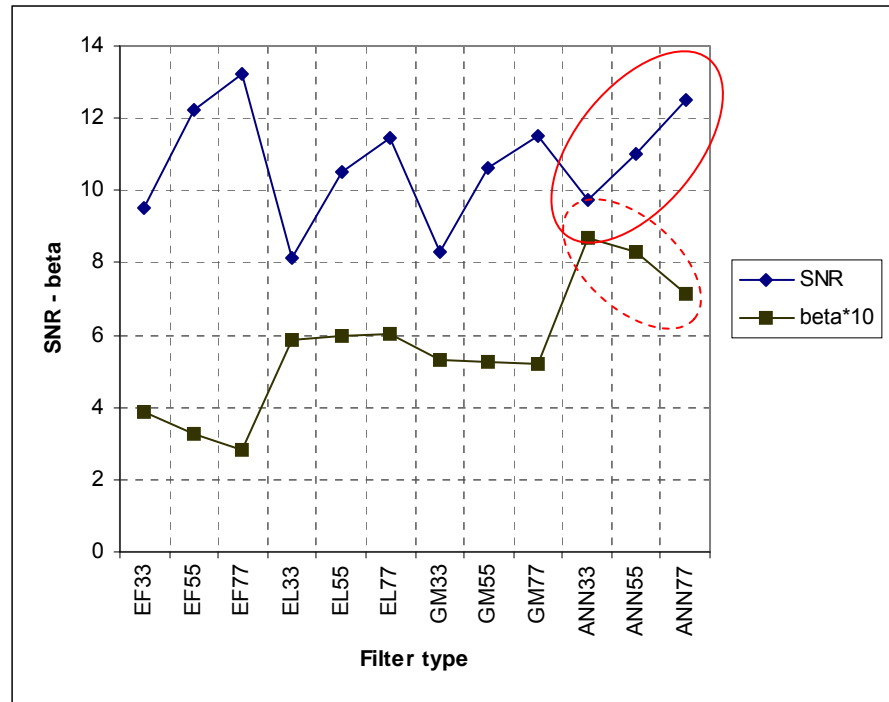
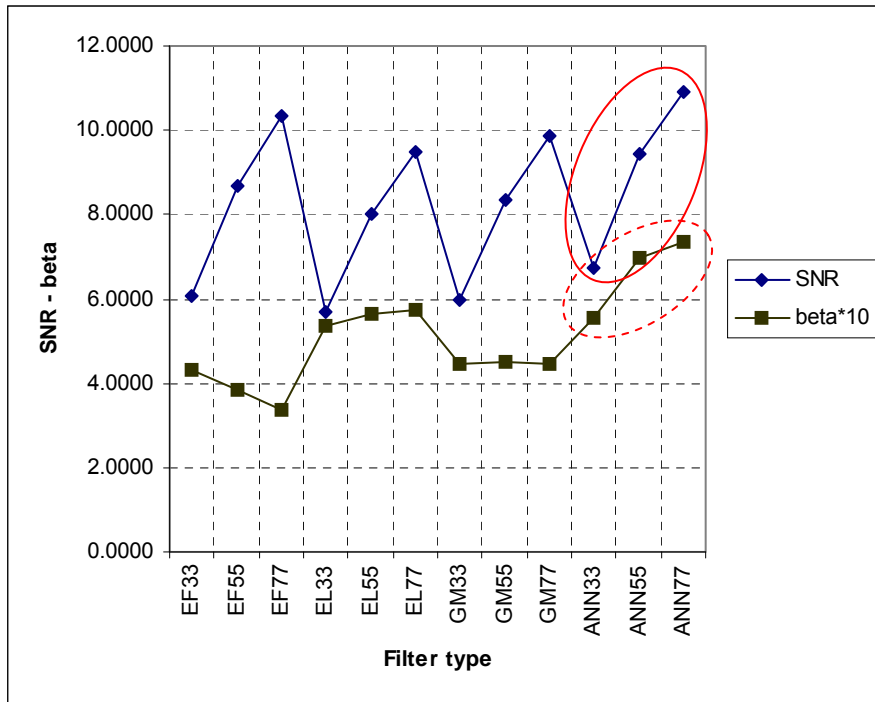
$$\Delta CV_i = \frac{\left(\frac{\sigma_{\hat{I}_i} - \sigma_{R_i}}{\mu_{\hat{I}_i}} \right)}{\frac{\sigma_{R_i}}{\mu_{R_i}}}$$

$$MSE_i = \frac{1}{K_i} \sum_{j=1}^{K_i} [\hat{I}_i(j) - R_i(j)]^2$$

1. Noise removal



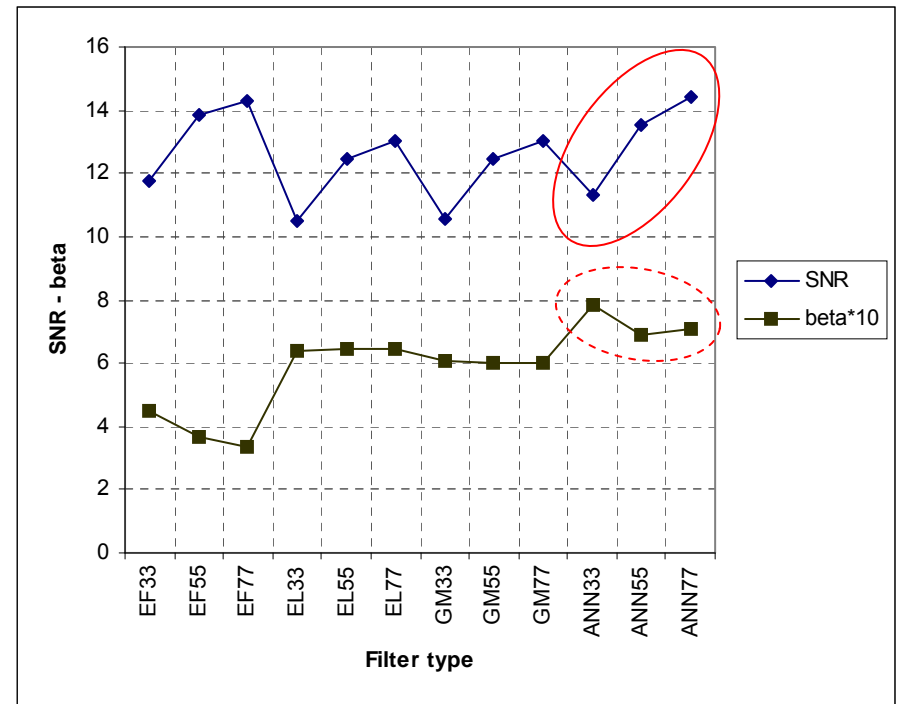
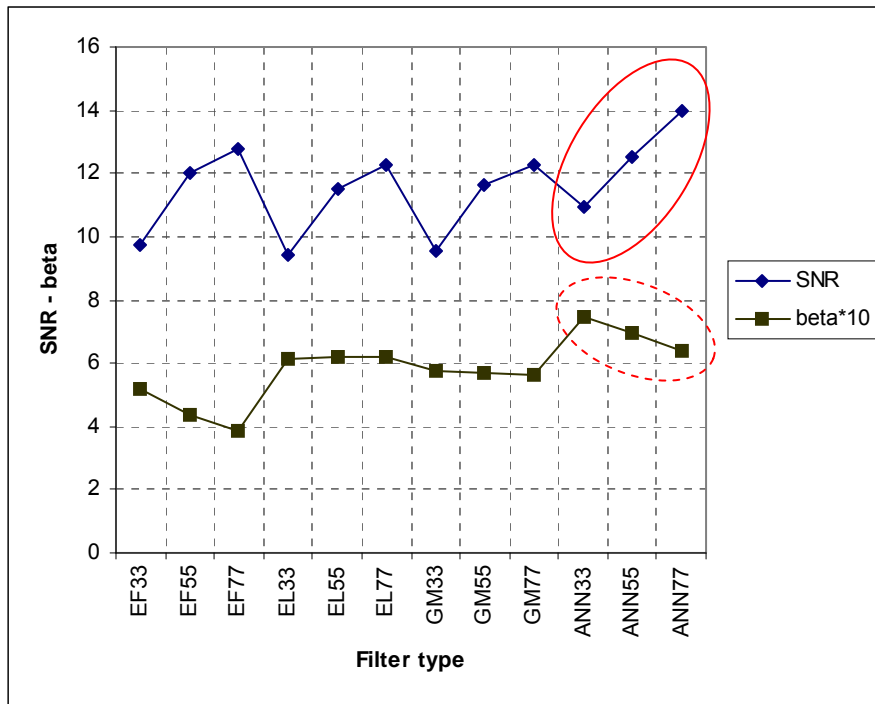
- New approach: performance evaluation
 - Image statistics (1 look, 2 looks)



1. Noise removal



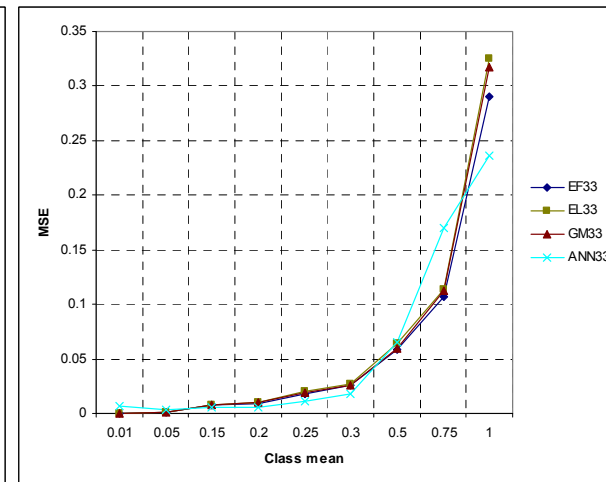
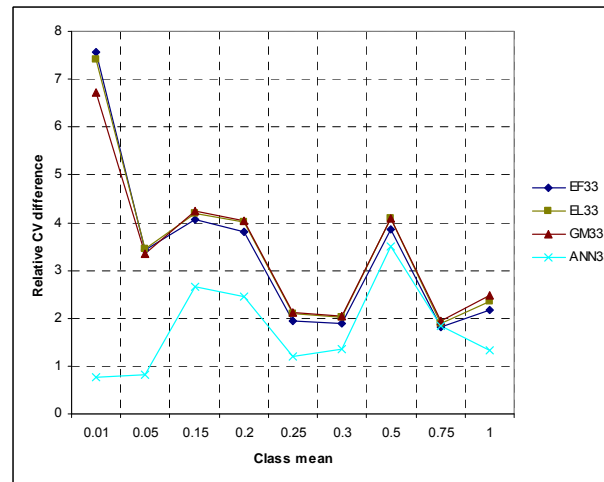
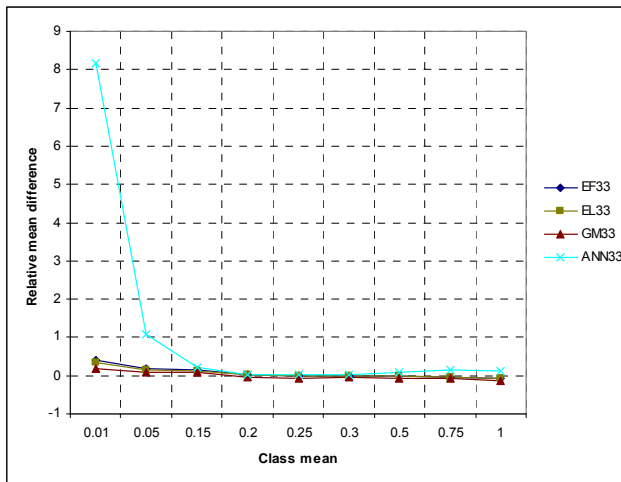
- New approach: performance evaluation
 - Image statistics (3 looks, 4 looks)



1. Noise removal



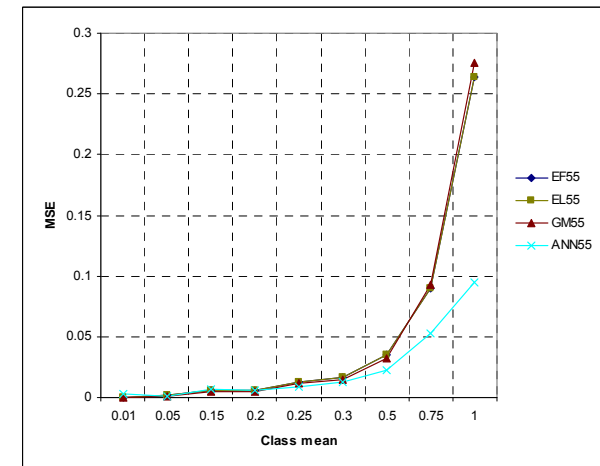
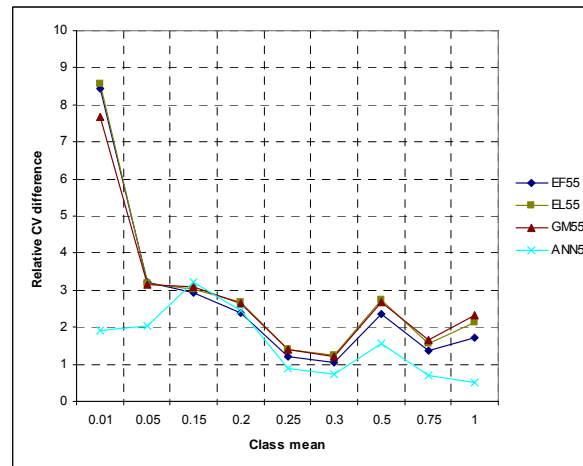
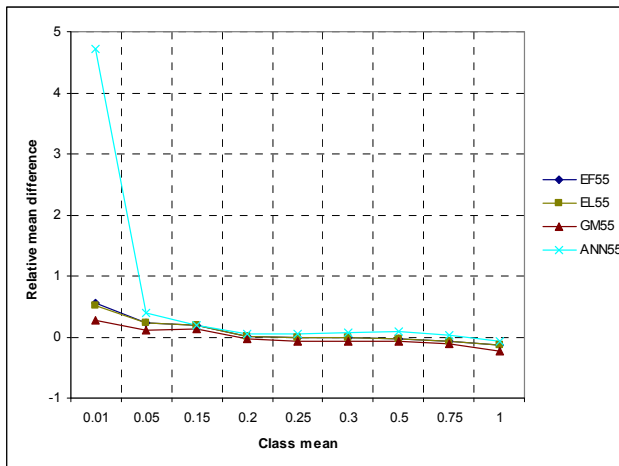
- New approach: performance evaluation
 - Class statistics (1 look, 3x3)



1. Noise removal



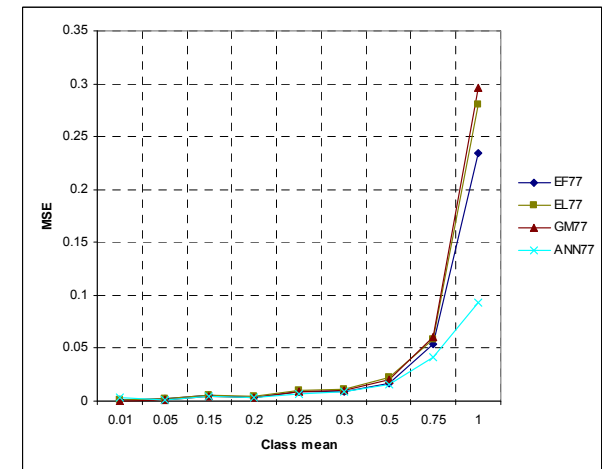
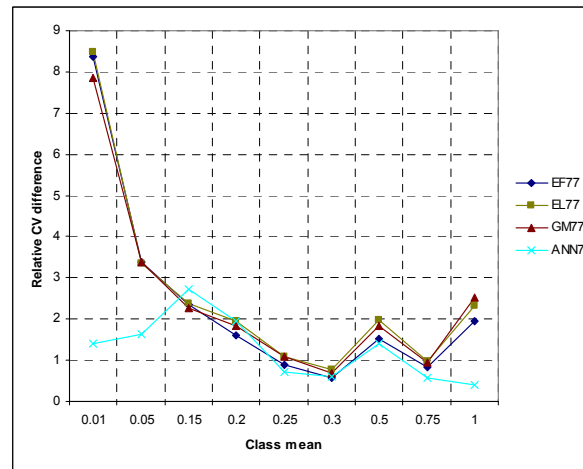
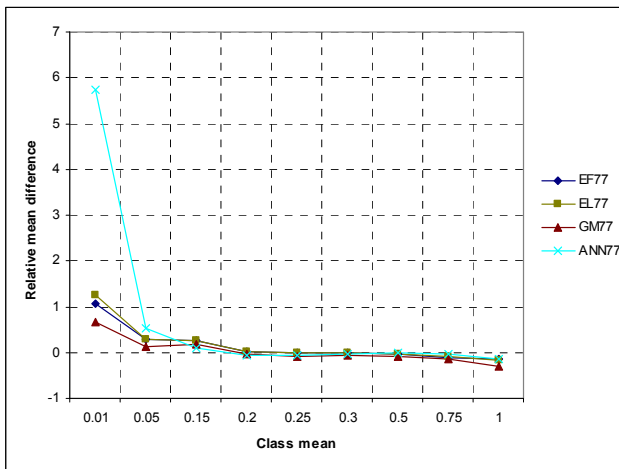
- New approach: performance evaluation
 - Class statistics (1 look, 5x5)



1. Noise removal



- New approach: performance evaluation
 - Class statistics (1 look, 7x7)



1. Noise removal



■ New approach: performance evaluation

□ Real SAR image (3 looks)

□ RAMSES image (1 look)

□ Noise removal

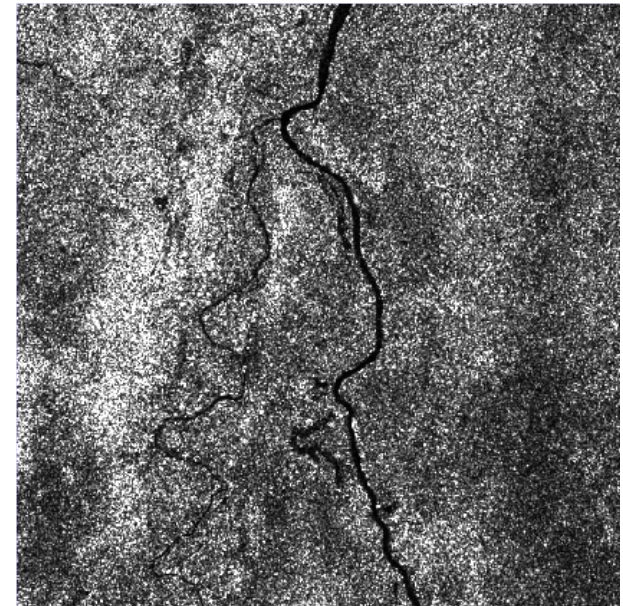
■ Enhanced Frost 7x7

■ Enhanced Lee 7x7

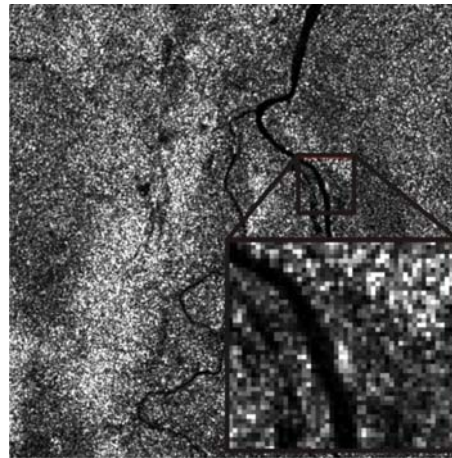
■ Gamma MAP 7x7

■ ANN 7x7

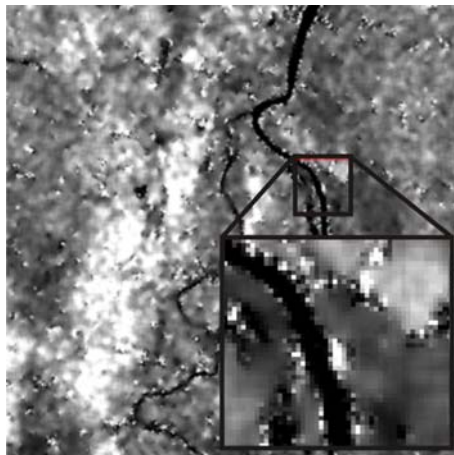
□ Visual comparison



1. Noise removal



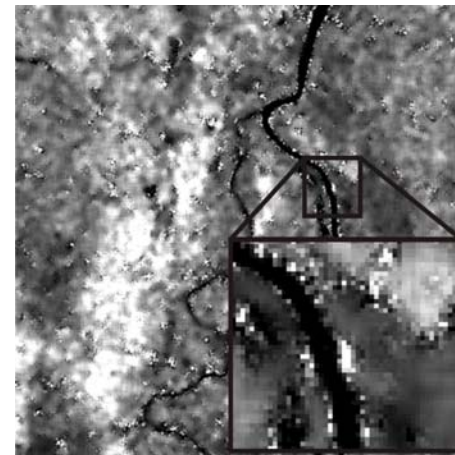
Speckled image



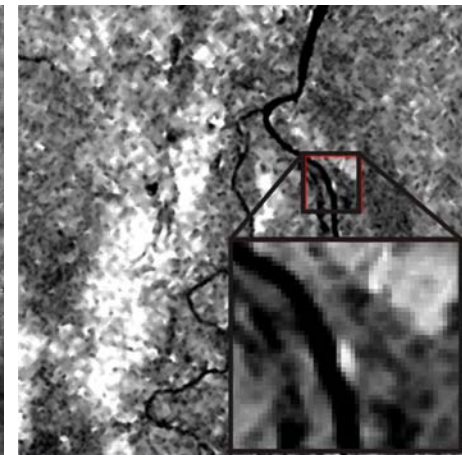
Enhanced Frost 7x7



Enhanced Lee 7x7



Gamma Map 7x7

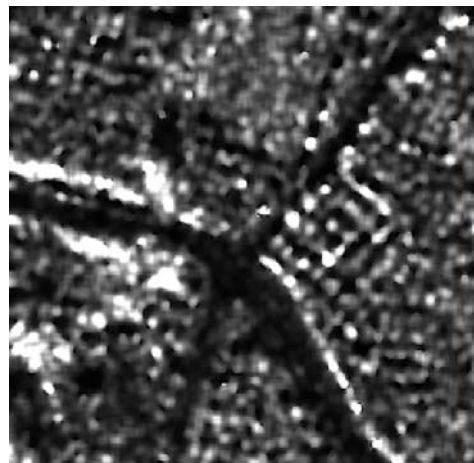


ANN 7x7

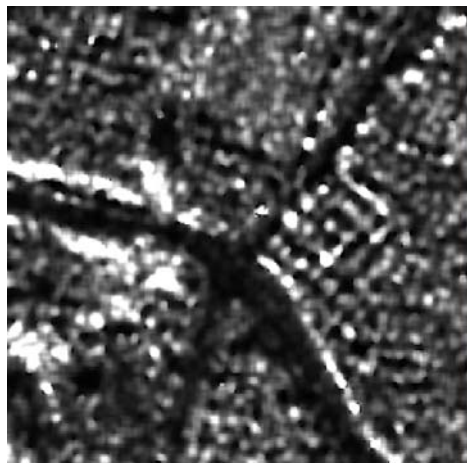
1. Noise removal



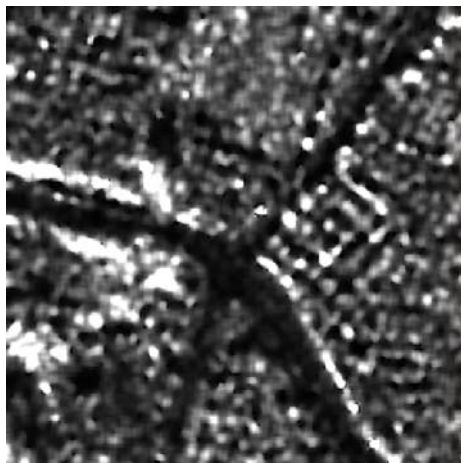
Speckled image



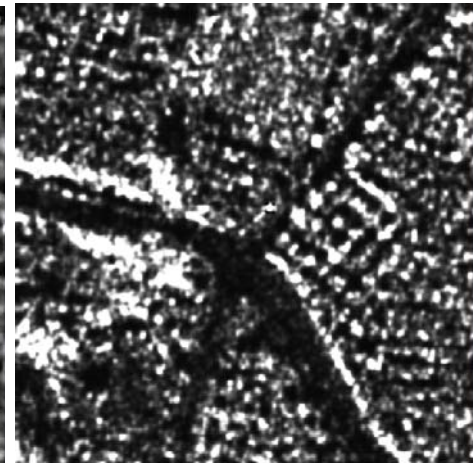
Enhanced Frost 7x7



Enhanced Lee 7x7



Gamma Map 7x7



ANN 7x7

1. Noise removal



■ New approach: future plans

- Fine tuning of evaluation measures
- Paper: “*Training learning machines on artificially generated data: a novel approach to SAR speckle removal*”
- Paper: “*Learning from artificially generated data: a novel approach to sub-pixel mapping*”

Items of this talk



1. Noise removal

- › Artificial neural network denoising technique

Items of this talk



1. Noise removal

› Artificial neural network denoising technique

2. Olive orchard delineation

› Wavelet-based segmentation technique

2. Orchard delineation



- Shortcomings of existing methods
 - Subjective: visual interpretation
 - Most automatic procedures designed for tree isolation
 - Stand delineation through image segmentation
 - MOSS (Hay et al., 2005)
 - Problems when stand are spectrally alike

- New approach: wavelet-based image segmentation

2. Orchard delineation



- New approach: stages
 - Developing stage: artificially generated imagery
 - Application stage: real ADS40 imagery

2. Orchard delineation

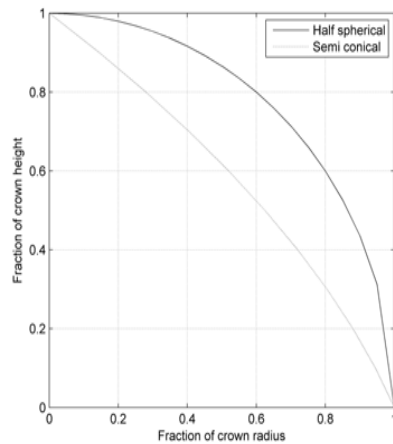
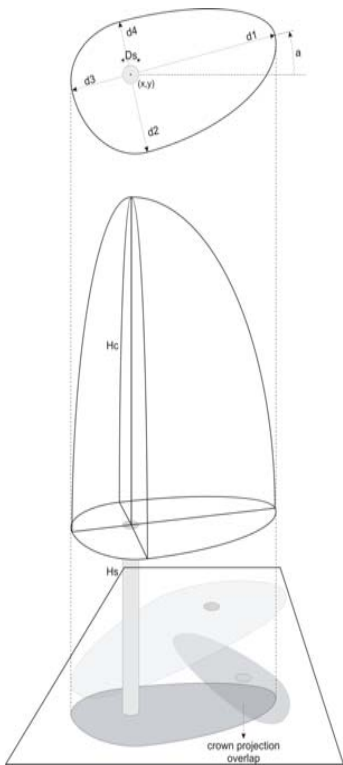


- New approach: developing stage
 - Generation of artificial remote sensing data
 - 1) Model the artificial tree
 - 2) Generation of 3-D artificial forest
 - 3) Illumination of 3-D forest (ray-tracing model) and determination of sensor response

2. Orchard delineation



- New approach: developing stage
 - Generation of artificial remote sensing data

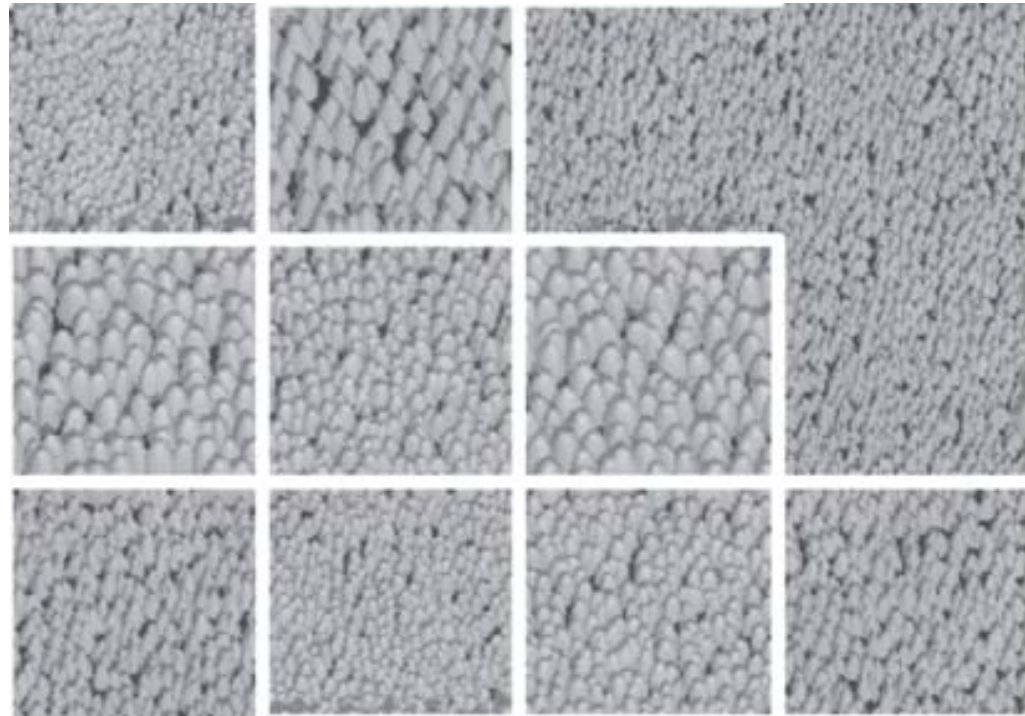
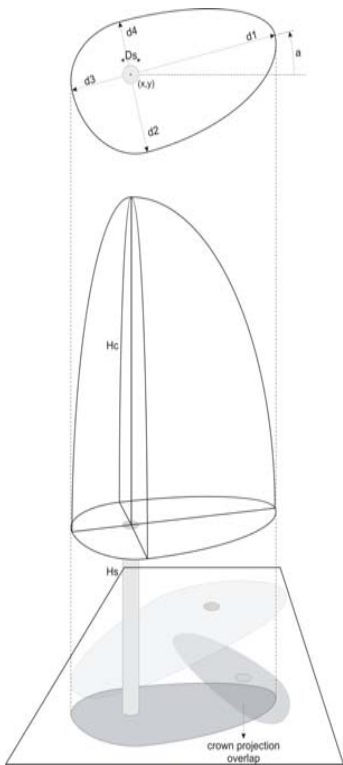


Variable	Distribution	Symbol in Figure 1
stem height	normal	Hs
crown height	normal	Hc
stem diameter	normal	Ds
crown shape	half sphere / semi conical	
crown radii	normal	d1, d2, d3, d4
stem position	uniform	(x,y)
orientation	uniform	a
spectral characteristics	normal	

2. Orchard delineation



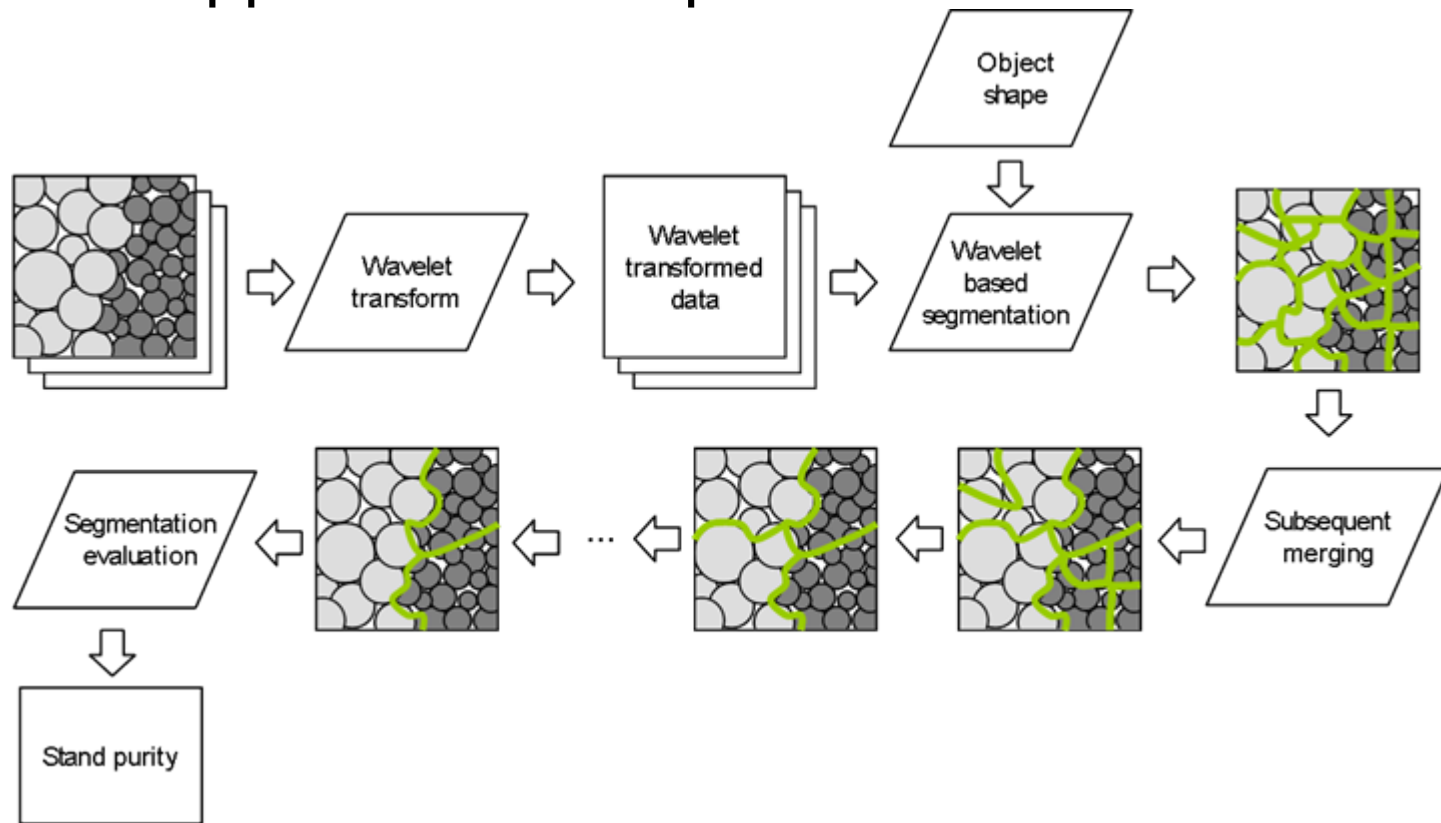
- New approach: developing stage
 - Generation of artificial remote sensing data



2. Orchard delineation



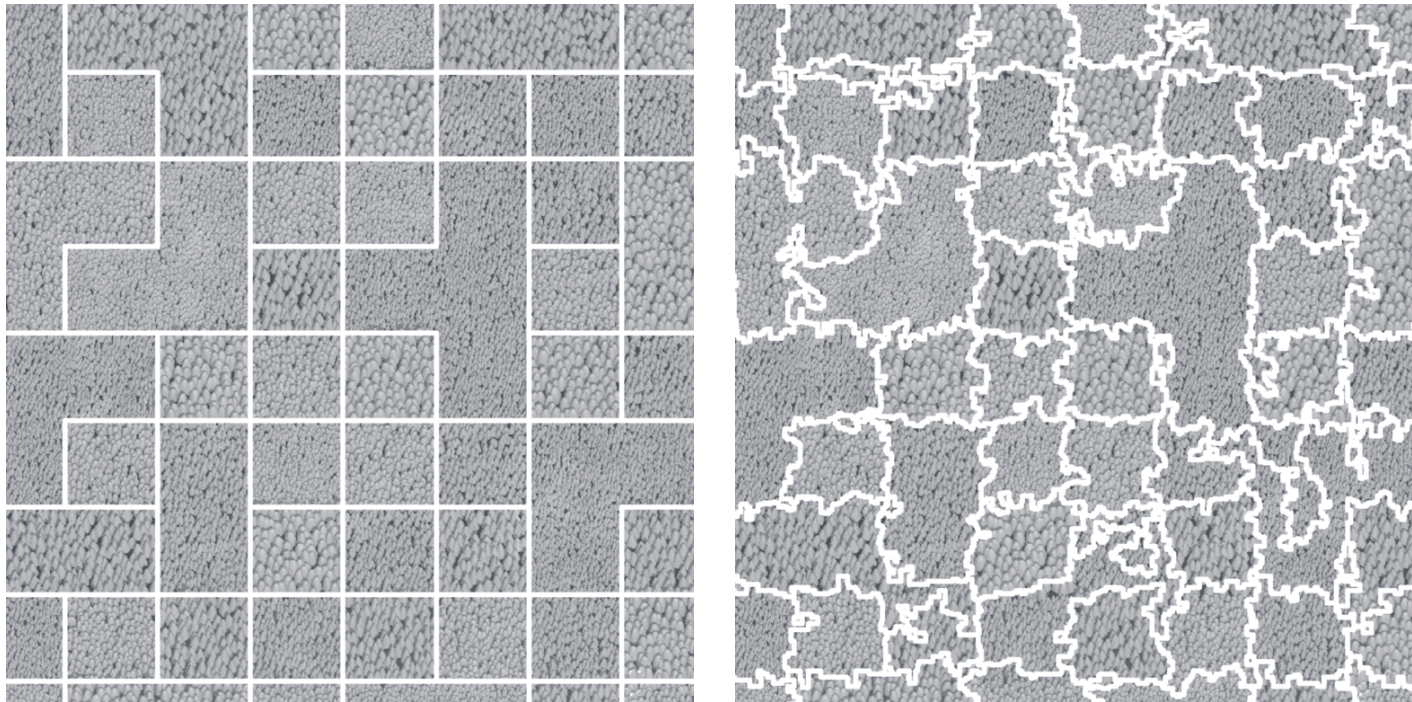
■ New approach: concept



2. Orchard delineation



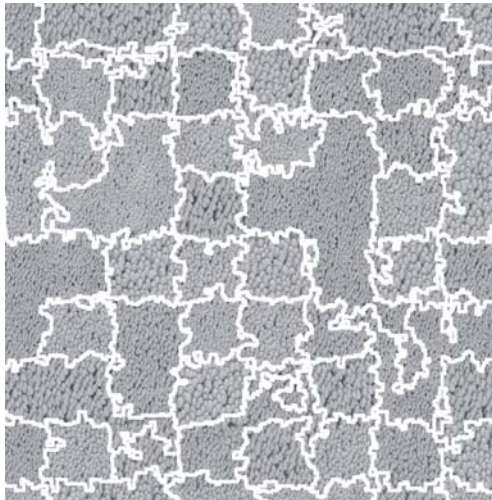
- New approach: concept



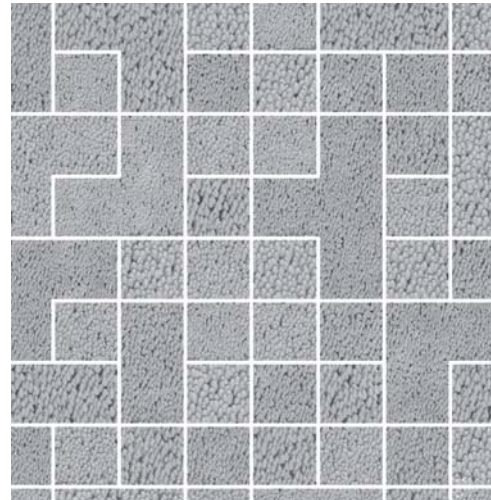
2. Orchard delineation



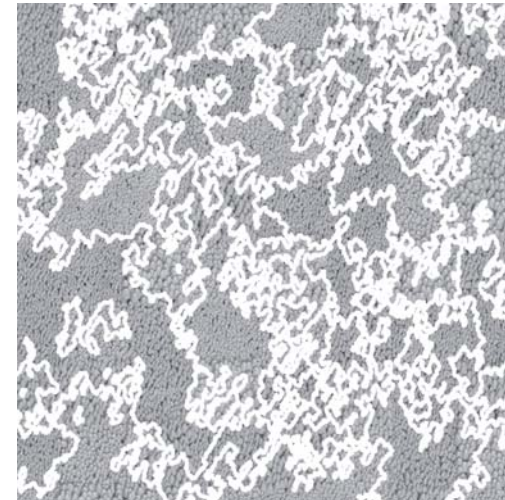
- New approach: performance evaluation
 - Qualitative: visual comparison



Wavelet-based segmentation



Target



Spectral-based segmentation

2. Orchard delineation



- New approach: performance evaluation
 - Qualitative: visual comparison
 - Quantitative: segmentation evaluation measures

- Purity index (PI)

$$PI(p) = \sum_{i=1}^S \frac{a_{ip}^2}{a_i \times a_p}$$

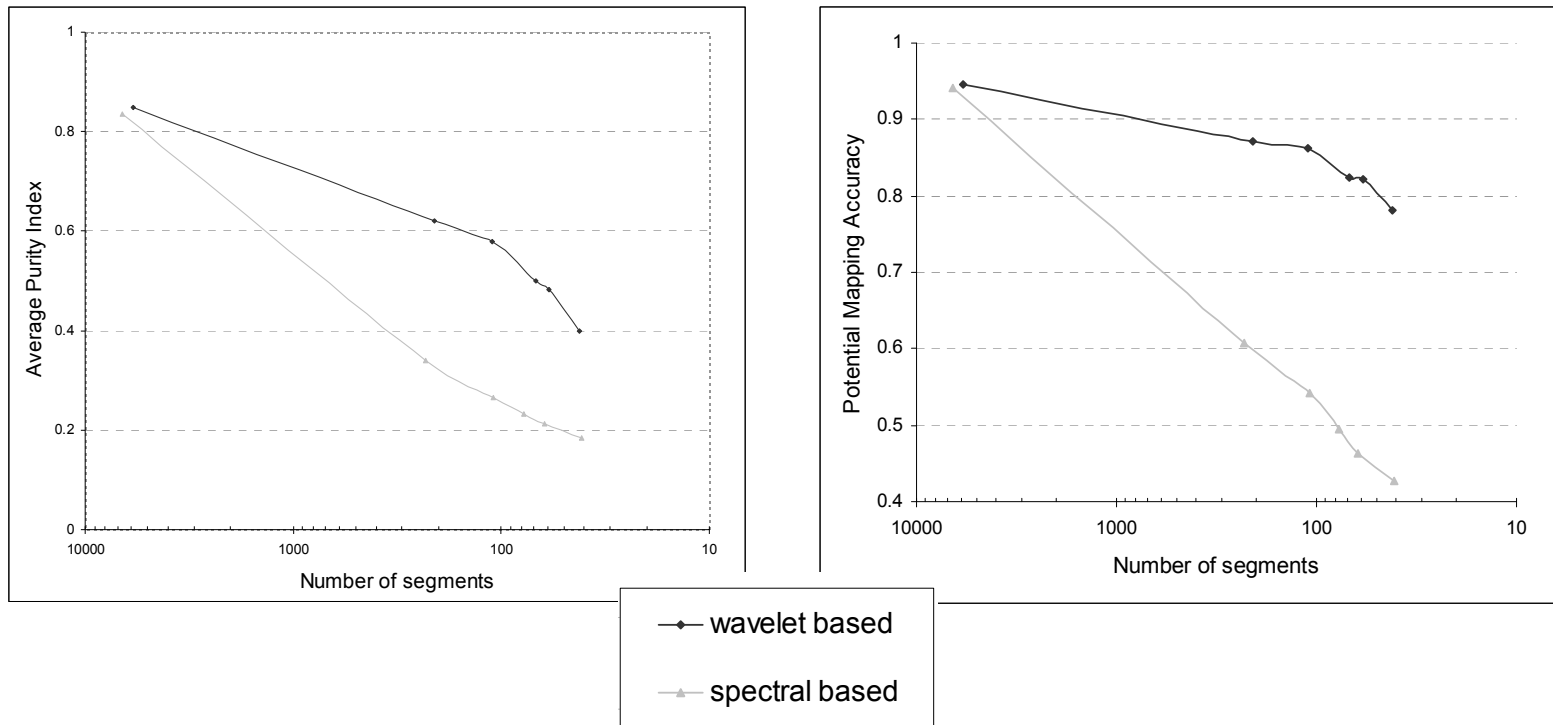
- Potential Mapping Accuracy (PMA)

$$PMA = \frac{C_{\max}}{T} \text{ with } C_{\max} = \sum_{i=1}^S \max(n_{i1}, n_{i2}, \dots, n_{in_c})$$

2. Orchard delineation



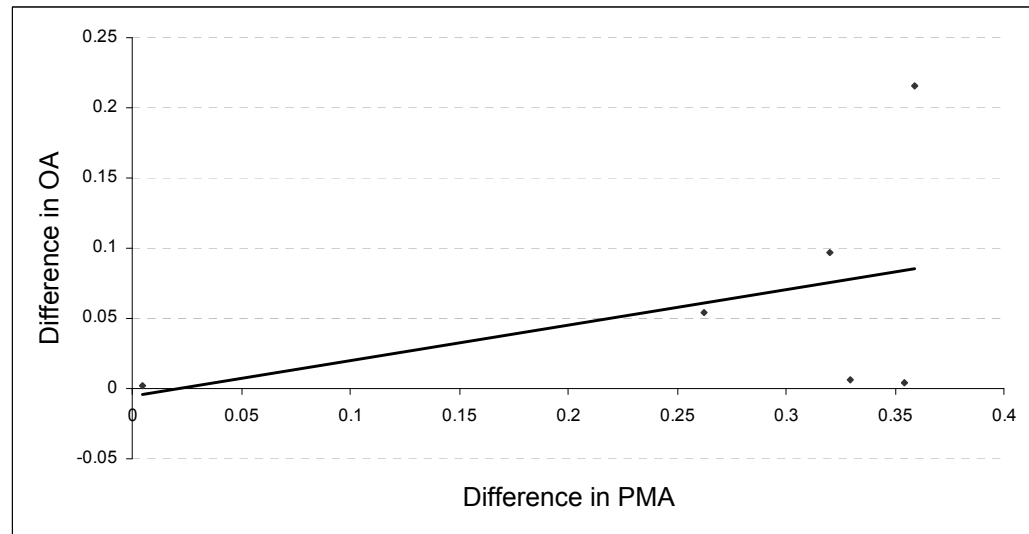
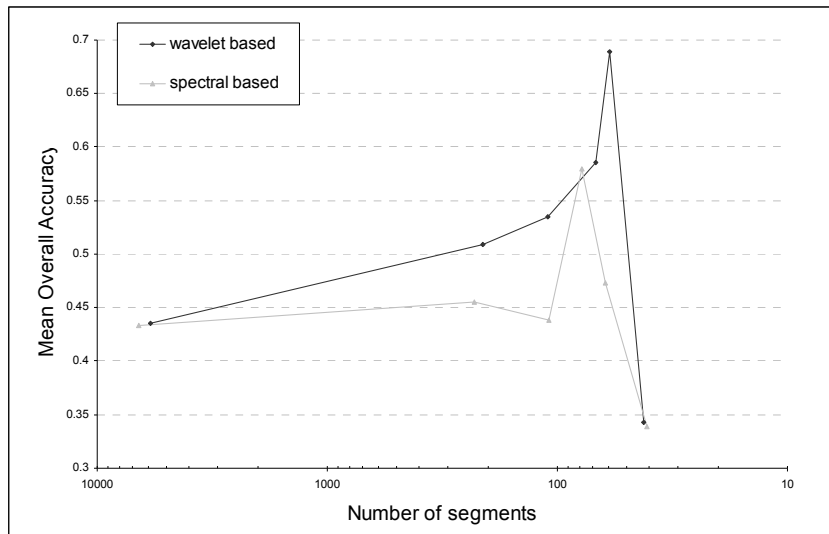
- New approach: performance evaluation



2. Orchard delineation



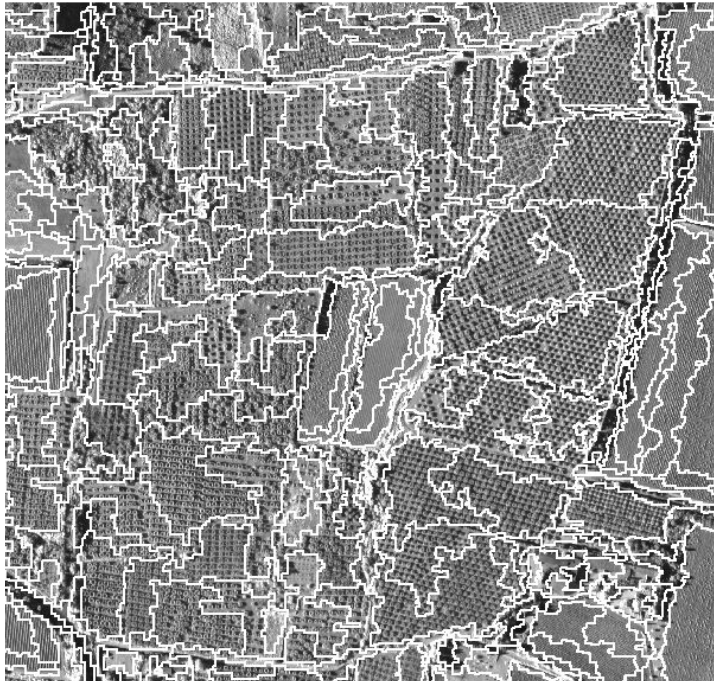
- New approach: performance evaluation



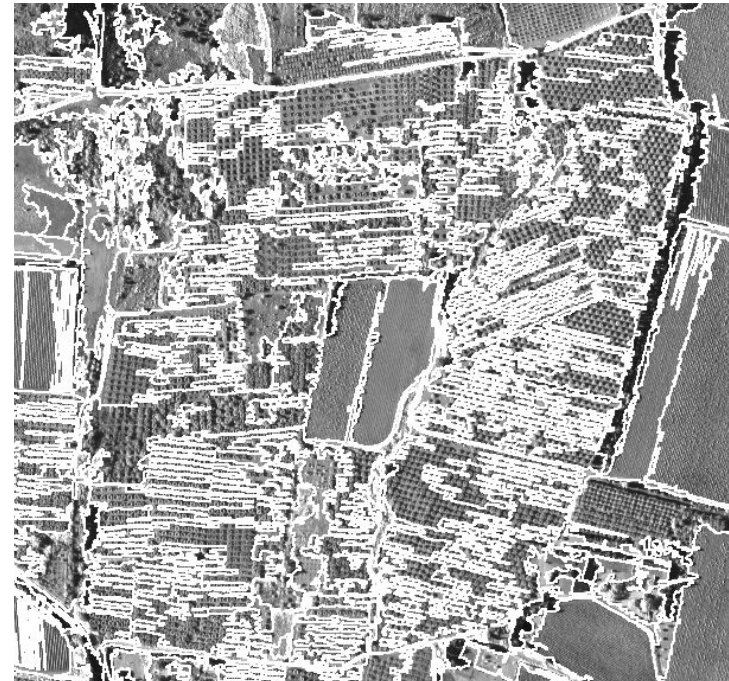
2. Orchard delineation



- New approach: application stage



Wavelet-based segmentation

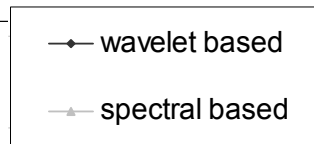
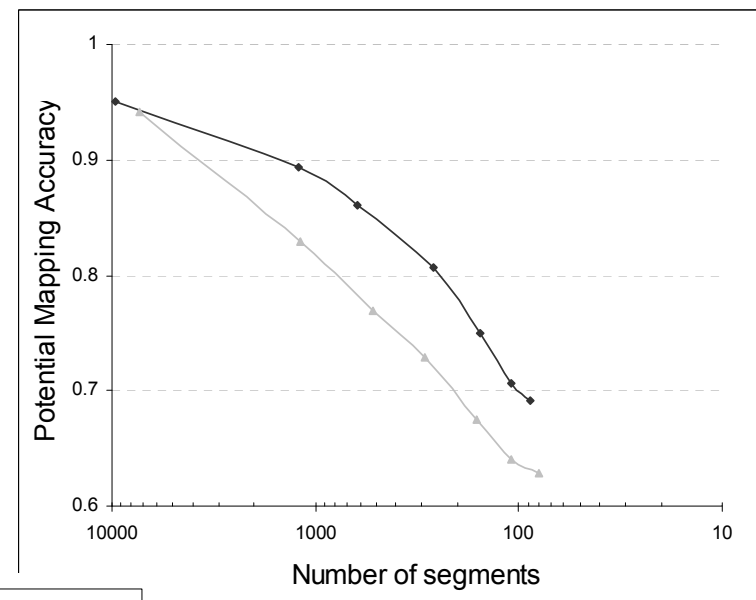
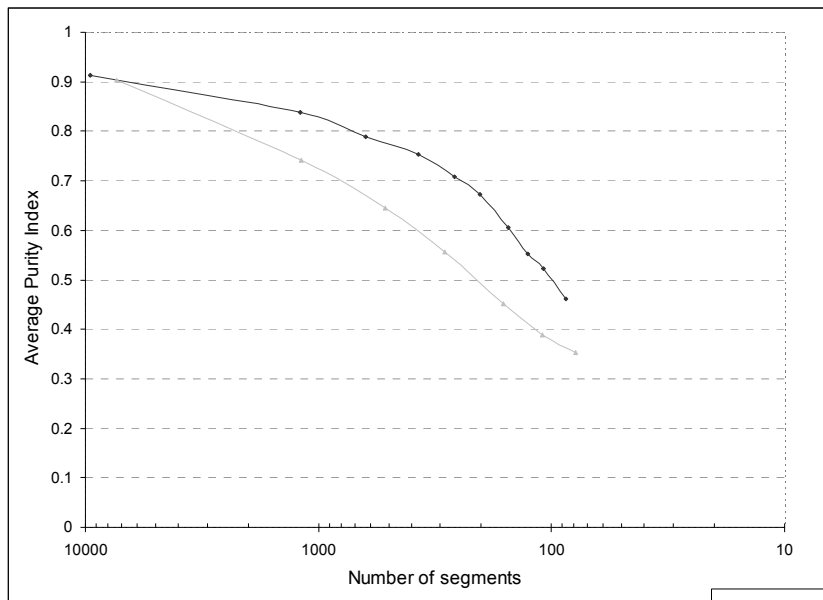


Spectral-based segmentation

2. Orchard delineation



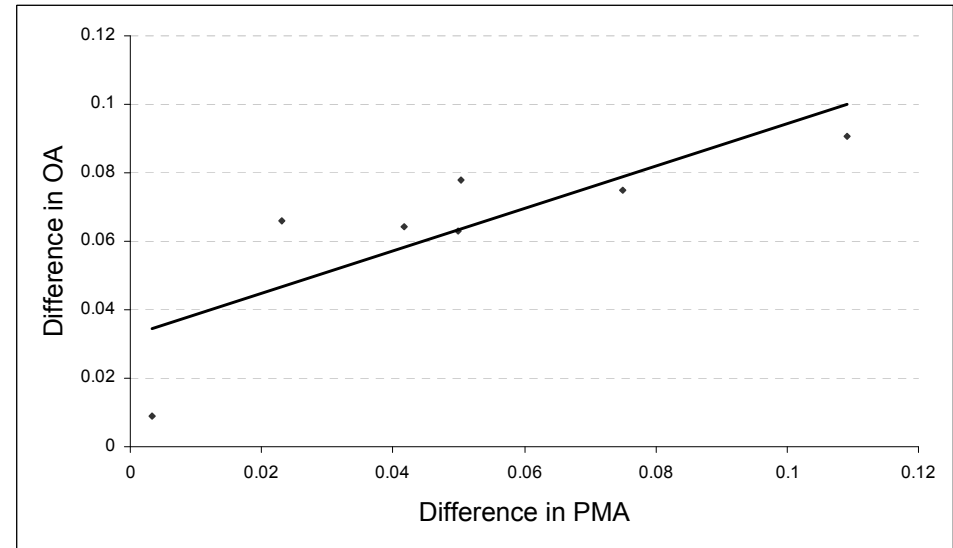
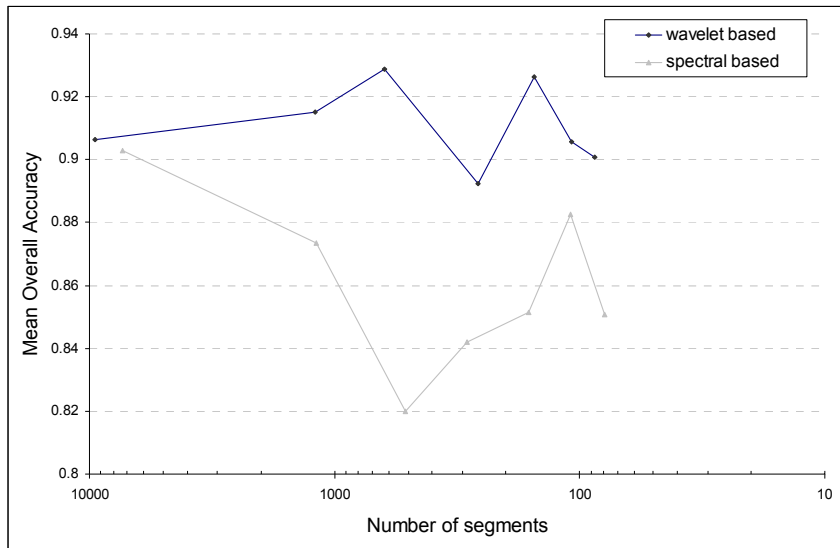
■ New approach: application stage



2. Orchard delineation



■ New approach: application stage



2. Orchard delineation



- New approach: future plans
 - Automatic stand delineation: VHR image segmentation
 - Image texture
 - Object shape
 - Impact of texture versus shape for stand delineation for forest stands with increasing boundary complexity

2. Orchard delineation



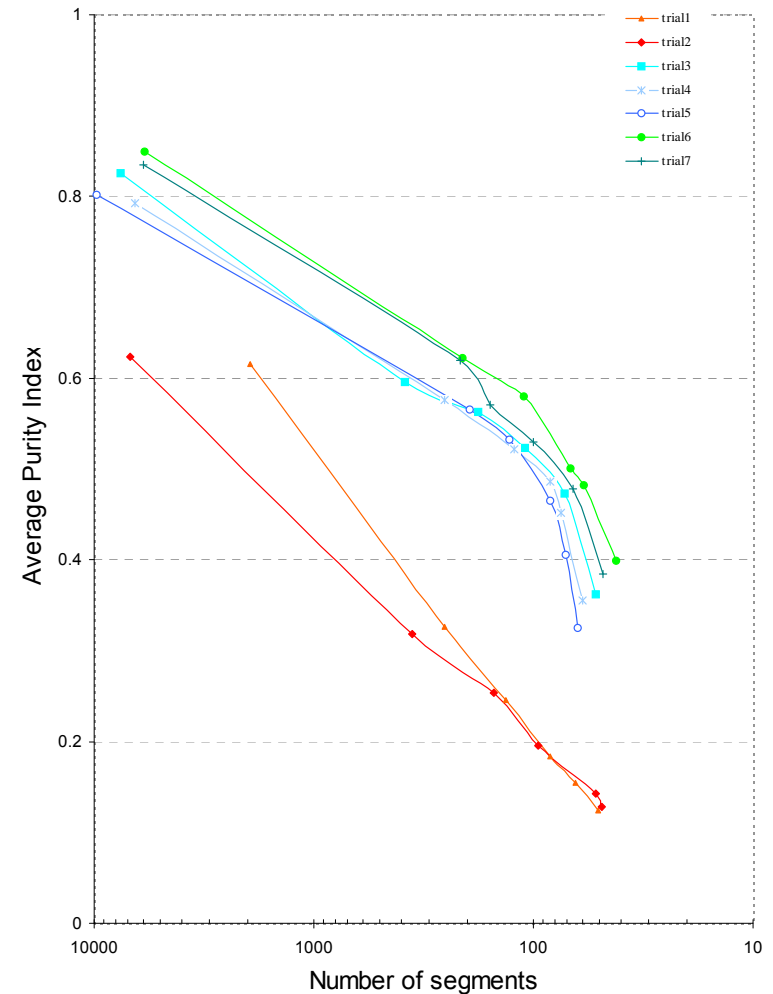
- New approach: future plans
 - Modest experiment
 - Impact of compact object shape tested on artificially generated forest consisting of squared forest stands
 - By weighing texture and shape in heterogeneity definition of segmentation process
 - Resultant segmentations quantitatively evaluated by assessing stand purity (PI)

2. Orchard delineation



- New approach: future plans
 - Modest experiment

Trial	$w/(1-w)$	$w_{cmpt}/(1-w_{cmpt})$
1	1 / 0	NA
2	0.1 / 0.9	0.9 / 0.1
3	0.8 / 0.2	0.9 / 0.1
4	0.2 / 0.8	0.9 / 0.1
5	0.5 / 0.5	0.9 / 0.1
6	0.8 / 0.2	0.1 / 0.9
7	0.8 / 0.2	0.5 / 0.5



2. Orchard delineation



- New approach: future plans
 - ≠ forest stand shapes: triangles, stars, Archimedean spirals
 - ≠ definitions of shape heterogeneity
 - Real VHR optical imagery

2. Orchard delineation



- New approach: future plans
 - Paper: “*Semi-automated forest stand delineation using wavelet-based segmentation of very high resolution optical imagery*”, In: T. Blaschke, S. Lang, G. Hay (Eds.), Object-Based Image Analysis: Spatial Concepts for Knowledge-driven Remote Sensing Applications (accepted)
 - Paper: “*Forest stand delineation: texture versus shape*”, Proceedings of the ForestSat2007 symposium, Montpellier, France
 - Paper: “*Automatic forest stand delineation: the impact of texture and shape*”

Items of this talk



1. Noise removal

› Artificial neural network denoising technique

2. Olive orchard delineation

› Wavelet-based segmentation technique

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 - › Wavelet-based regression technique

3. Orchard SDE



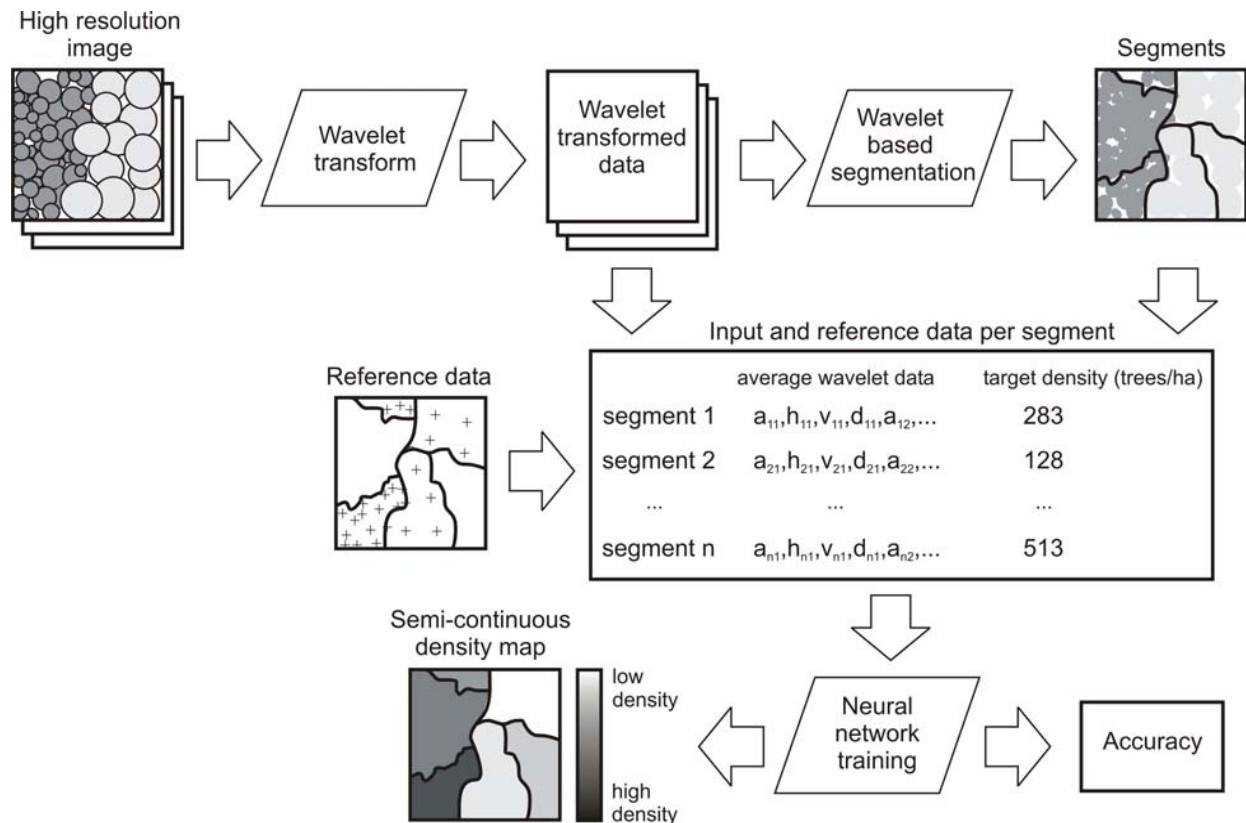
- Drawback of current techniques
 - Existing SDE techniques are largely based on identification of individual trees

- New approach
 - Alternative technique: SDE is based on small-area statistics characterizing local texture
 - Small-area \approx objects $<$ management unit (tree stand)
 - Semi-continuous stand density maps

3. Orchard SDE



■ New approach: concept



3. Orchard SDE



- New approach: performance evaluation
 - Two datasets: artificial and real ADS40 image
 - \leftrightarrow Local Maximum Filter (LMF)
 - Quantitative error measures
 - Correlation (ρ)
 - Root Mean Square Error (RMSE)
 - Mean Absolute Error (MAE)

$$RMSE = \sqrt{\frac{\sum_{s=1}^n (prediction_s - target_s)^2}{n}}$$

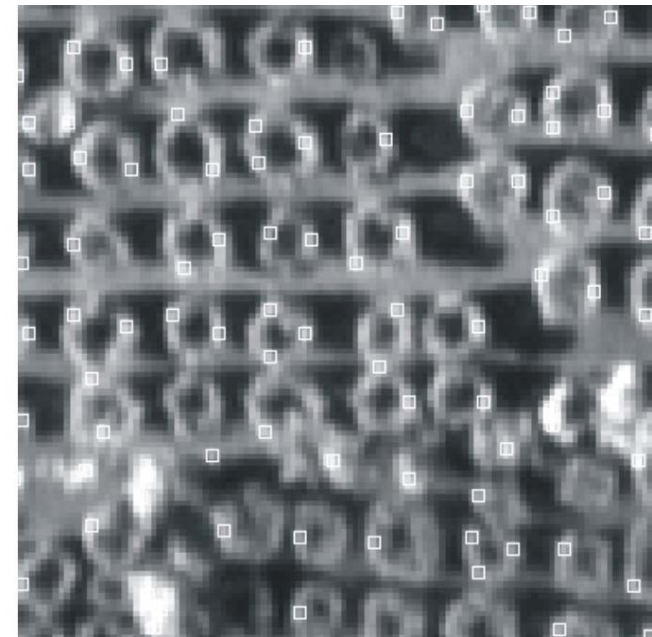
$$MAE = \frac{\sum_{s=1}^n |prediction_s - target_s|}{n}$$

3. Orchard SDE



- New approach: performance evaluation
 - Ten fold cross validation: estimation of average correlation, RMSE and MAE

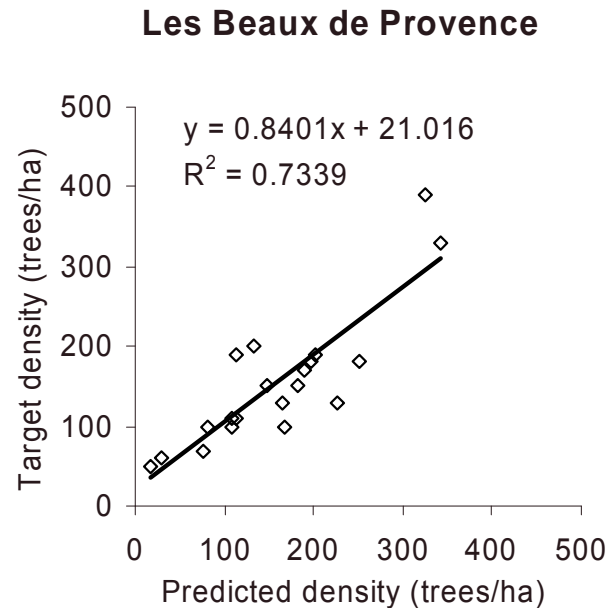
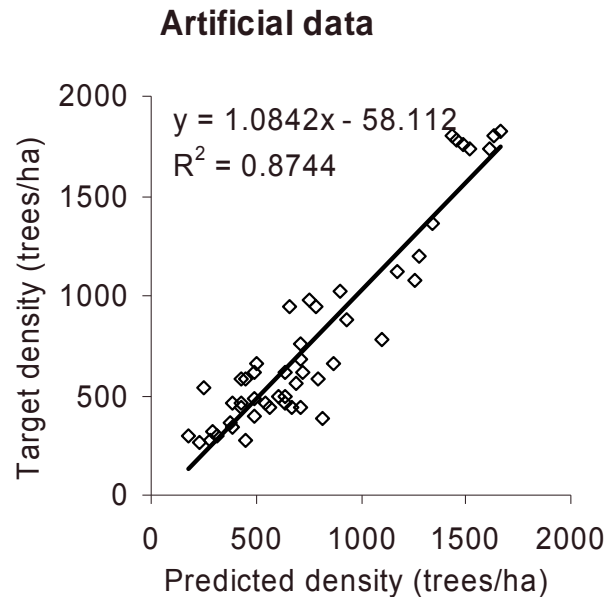
	Correlation	RSME	MAE
Artificial imagery			
LM	0.677	319.7	242.3
Wavelet-based	0.909	195.2	149.3
ADS40			
LM	NA	NA	NA
Wavelet-based	0.781	60.9	48.5



3. Orchard SDE



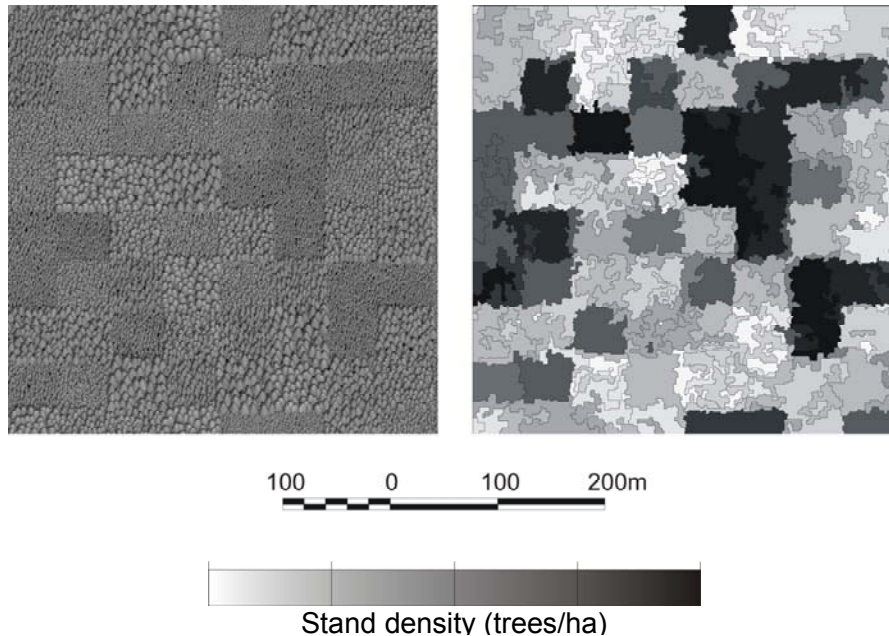
- New approach: performance evaluation



3. Orchard SDE



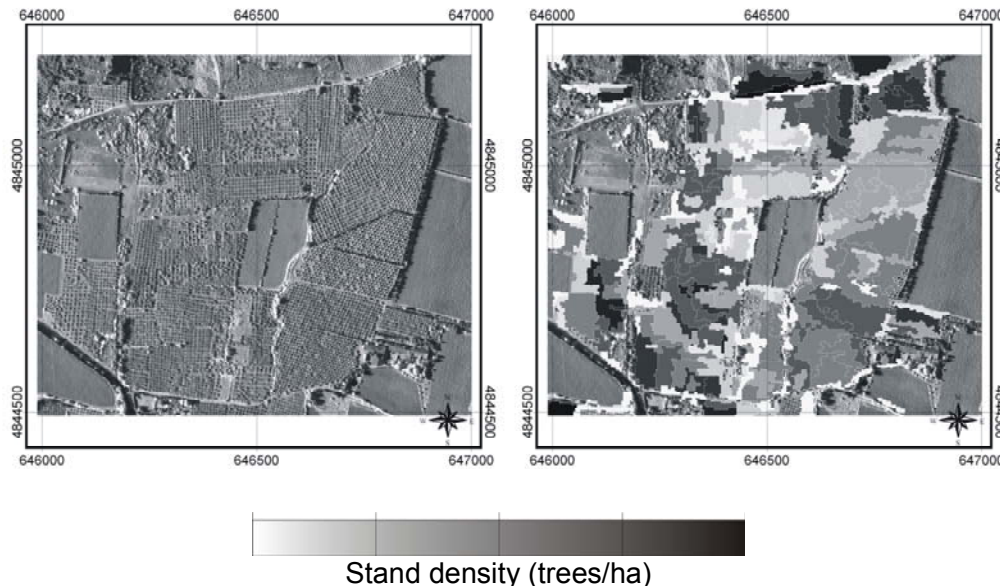
- New approach: performance evaluation



3. Orchard SDE



- New approach: performance evaluation



2. Orchard delineation



- New approach: future plans
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 - Method fine tuning for olive trees

2. Orchard delineation



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1. Noise removal
 - › Artificial neural network denoising technique
2. Olive orchard delineation
 - › Wavelet-based segmentation technique
3. Olive orchard stand density estimation
 - › Wavelet-based regression technique

Final remark



- Several methodologies developed
 - ❑ Based on artificially generated data
 - ❑ Applied to VHR optical data
 - ❑ Not yet implemented on VHR radar data

THANK YOU FOR YOUR ATTENTION



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