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Support Vector Machines Based Filtering of Lidar Data: A Grid Based Method

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Outlines

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- Filtering of Lidar Data
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- Methodology
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  a. Analyzing Filtering Errors
- Advantages of the proposed method & future Work

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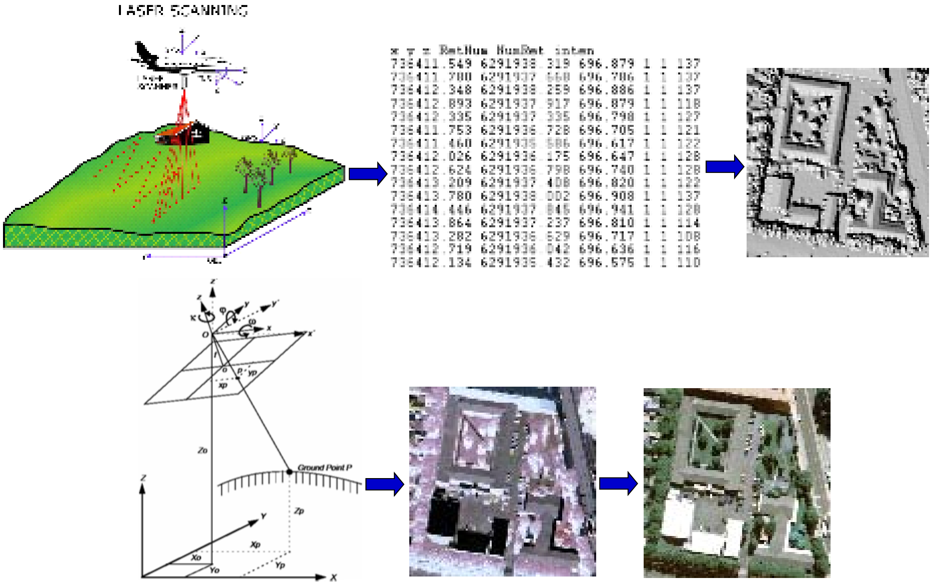
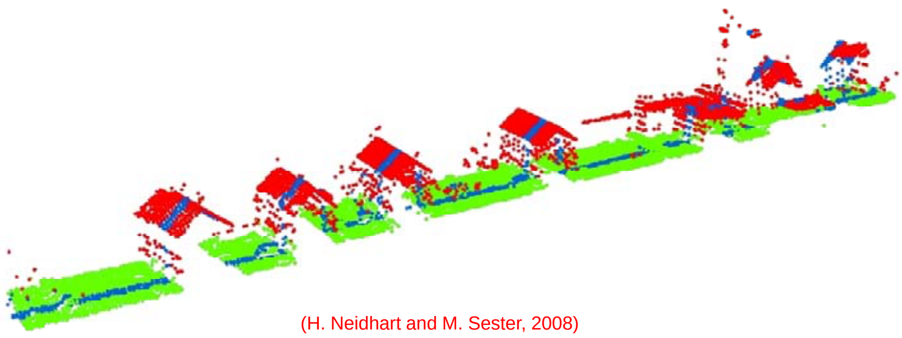
Lidar VS Photogrammetry



Filtering of Lidar Data

Filtering is the process of separating on-terrain points (DTM) from points falling onto objects like buildings, cars, trees, and other natural and human made objects.



(H. Neidhart and M. Sester, 2008)

Main Approaches

a. Grid based filtering

- Slopes between a lidar point and its neighbours (Vosselman, 2000).
- Comparing local curvatures of point measurements (Haugerud and Harding, 2001).
- Linear prediction of a stationary random function (Passini and Jacobsen, 2002).
- Active contours (Elmqvist, 2002).
- mathematical morphology (Zhang et al., 2003).

b. original data based filtering

- Triangulated Irregular Network (TIN) (Axelsson, 2000).
- An elevation threshold and an expanding search window (Whitman et al., 2003).
- Orthogonal polynomials and road network (Abo Akel et al., 2004).
- Wavelets (Bartels, 2006).

Disadvantages of Existing approaches

- The requirement of a fixed window size and elevation difference thresholds.
- Inefficient performance in case of complex landscapes.
- High percentages of commission and omission errors (exceeds 15%).

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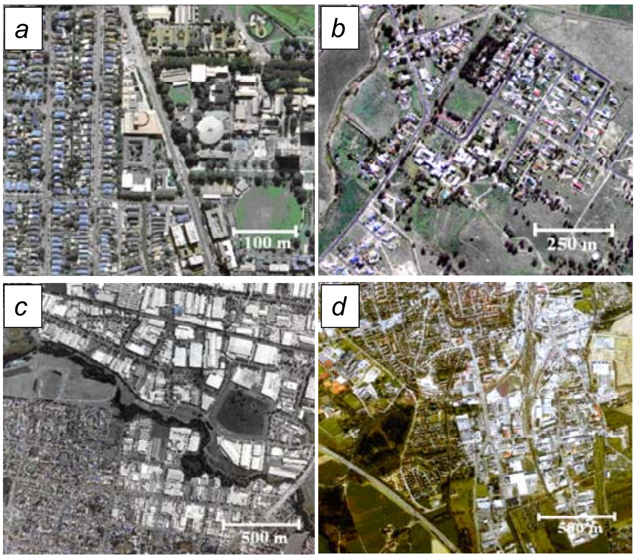
Study Area and Data Sources



Orthophotos for: (a) UNSW; (b) Bathurst; (c) Fairfield; and (d) Memmingen

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Characteristics of image datasets

Test area	Size(Km)	bands	pixel size (cm)	Camera	Look Angle (deg.)	
					along track	across track
UNSW	0.5 x 0.5	RGB	9	LMK1000	±30	±30
Bathurst	1 x 1	RGB	50	ADS40 Line scanner	Line scanner	46
Fairfield	2 x 2	RGB	15	LMK1000	±30	±30
Memmingen	2 x 2	CIR	50	TopoSys Falcon II line scanner	Line scanner	22

Characteristics of lidar datasets

	UNSW	Bathurst	Fairfield	Memmingen
	Optech ALTM 1225	Leica ALS50	Optech ALTM 3025	TopoSys
Spacing across track (m)	1.15	0.85	1.2	0.15
Spacing along track (m)	1.15	1.48	1.2	1.5
Vertical accuracy (m)	0.10	0.10	0.15	0.15
Horizontal accuracy (m)	0.5	0.5	0.5	0.5
Density (Points/m^2)	1	2.5	1	4
Sampling intensity (mHz)	11	150	167	125
Wavelength (µm)	1.047	1.064	1.047	1.56
Average altitude (m)	1100	1450	1500	800
Laser swath width (m)	800	777.5	700	750

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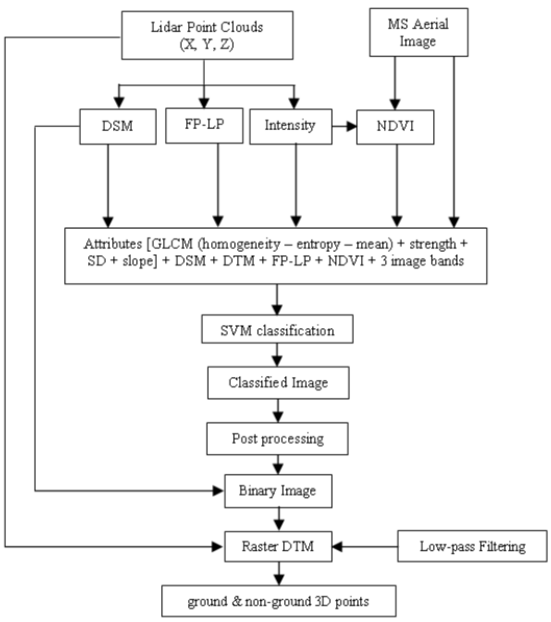
Methodology



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1. Data Pre-processing

The full set of generated attributes

Attributes	Attribute	R	G	B	I	DSM	nDSM
Spectral	Mean	●	●	●	●	●	●
	St. Deviation	●	●	●	●	●	●
	Strength	●	●	●	●	●	●
GLCM	Contrast	●	●	●	●	●	●
	Dissimilarity	●	●	●	●	●	●
	Homogeneity	●	●	●	●	●	●
	A.S.M	●	●	●	●	●	●
	Entropy	●	●	●	●	●	●
	Mean	●	●	●	●	●	●
	Variance	●	●	●	●	●	●
	Correlation	●	●	●	●	●	●
Height	SD	●	●	●	●	●	●
	Slope	●	●	●	●	●	●

R: Red, **G**: Green, **B**: Blue, **I**: Intensity/IR

DSM: Digital Surface Model, **nDSM**: Normalized Digital Surface Model

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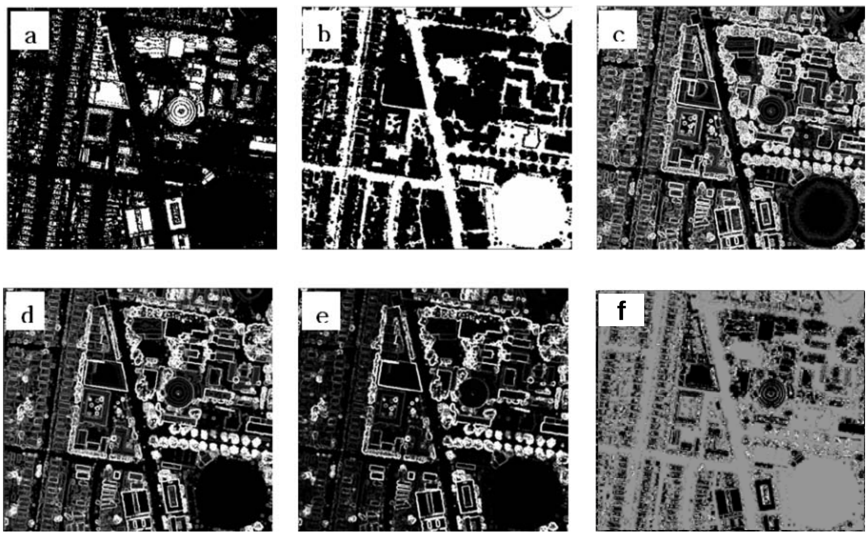

(a) GLCM-homogeneity of the nDSM, (b) GLCM-entropy of the nDSM,
(c) Slope percent of t he nDSM, (d) SD of the nDSM, (e) Texture strength of the nDSM,
(f) GLCM-contrast of the nDSM

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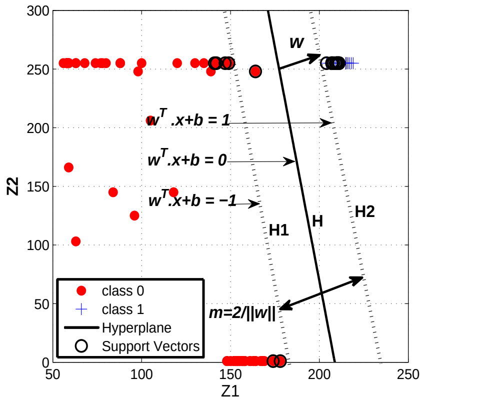
2. Support Vector Machines (SVMs) classification



Optimum separation plane in the (Z1, Z2) space

$$w.x + b = 0 \quad (1)$$

$$w.x_i + b \leq -1, \quad for \ class \ 0 \quad (2)$$

$$w.x_i + b \geq -1, \quad for \ class \ 1 \quad (3)$$

$$y_i[(w.x_i) + b] - 1 \geq 0 \quad \forall i \quad (4)$$

$$\min (1/2)\|w\|^2 + C\sum_{i=1}^{l} \xi_i$$
$$Subject \ to \ y_i[w\phi(x_i) + b] \geq 1 - \xi_i \quad (5)$$
$$\xi_i \geq 0, \ i = 1,2,.........,l$$

C is the penalty parameter which controls the edge balance of the error *ξ*. Using the technique of Lagrange multipliers, the optimization problem becomes:

$$\min \frac{1}{2}\sum_{i=1}^{l}\sum_{j=1}^{l} \alpha_i \alpha_j y_i y_j K(x_i, y_j) - \sum_{i=1}^{l} \alpha_i$$
$$Subject \ to \ \sum_{i=1}^{l} y_i \alpha_i = 0$$
$$0 \leq \alpha_i \leq C, i = 1,2,.....,l \quad (6)$$

Where $K(x_i, y_j) = \varphi(x_i), \varphi(y_j)$ is kernel function.

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Kernel functions used for the experiments

Kernel	Formula
Linear	$K(x, y) = x.y$
Gaussian RBF	$K(x, y) = \exp(-\gamma\|x - y\|^2)$
Polynomial	$K(x, y) = ((x.y) + 1)^d$
Sigmoid	$K(x, y) = \tanh(k(x.y) + 1)$

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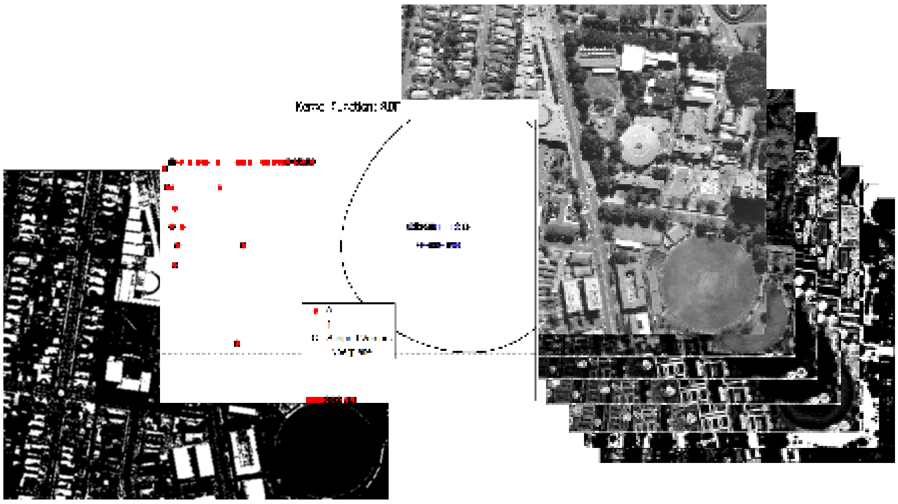
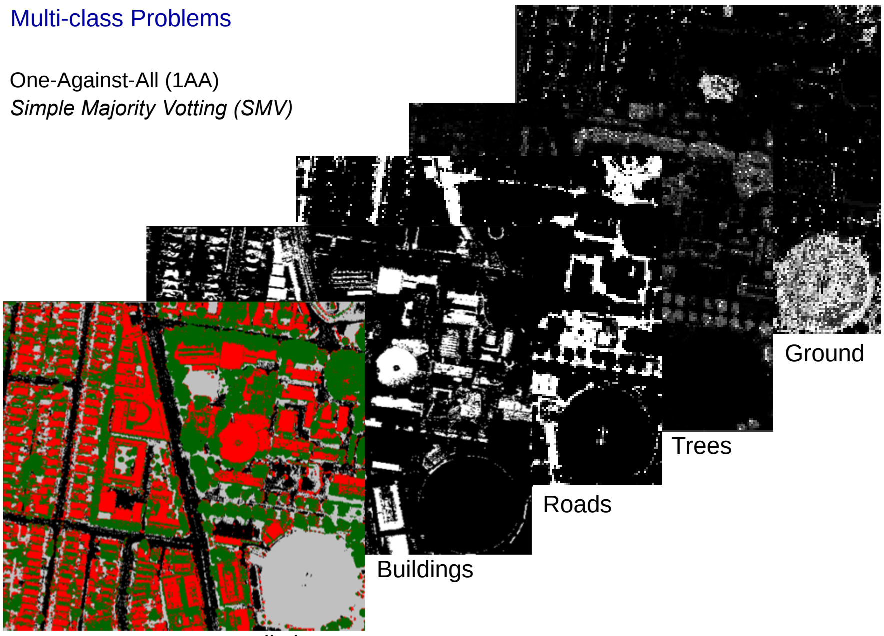
Image classification into Buildings and non-Buildings Based on SVMs

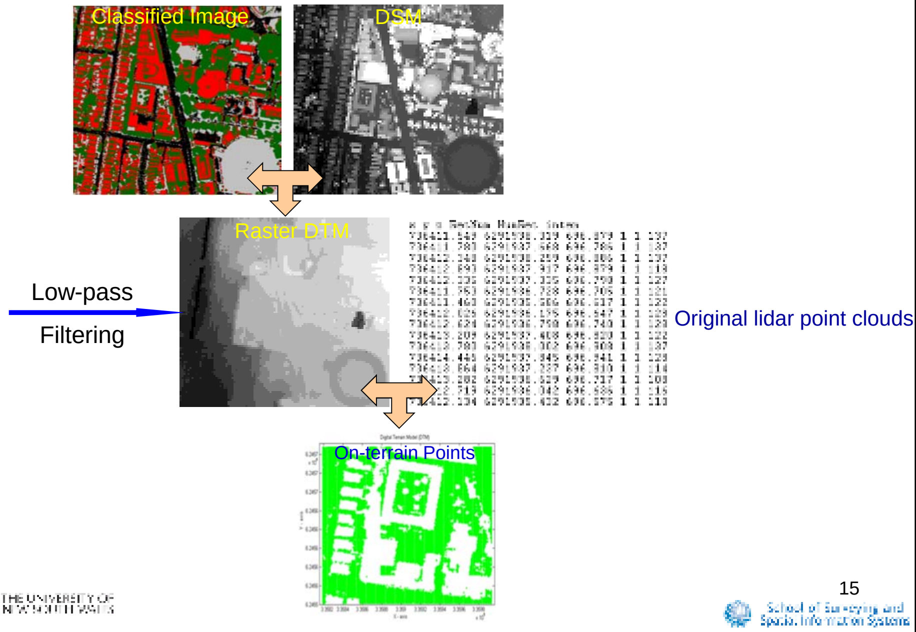


Multi-class Problems

One-Against-All (1AA)
Simple Majority Votting (SMV)



3. Filtering of the 3D lidar point clouds



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4. Analyzing Filtering Errors

a. Quantitative check of the filtering results

Definition of omission and commisssion errors (Congalton, 1991)

	ground	non-ground	
ground	a	b (omission error)	e = a + b
non-ground	c (commission error)	d	f = c + d
	g = a + c	h = b + d	n = a + b + c + d

Percentage of omission errors = b / e * 100%
Percentage of commission errors = c / f *100%
Percentage of total errors = (b + c) / n * 100%

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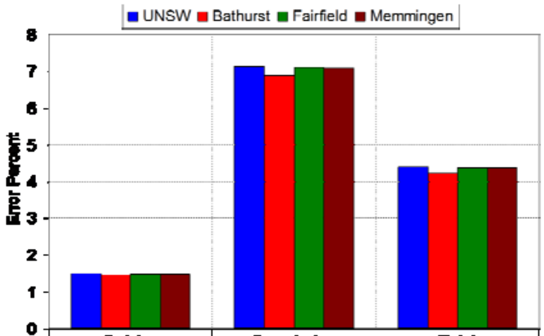

	Omission	Commission	Total
UNSW	1.49	7.12	4.38
Bathurst	1.44	6.88	4.23
Fairfield	1.48	7.06	4.35
Memmingen	1.48	7.07	4.35

Error comparison based on filtering using SVM for the four test areas

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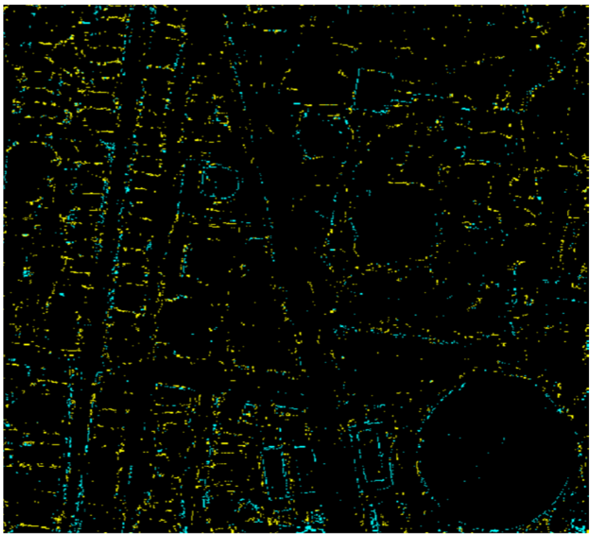
b. Qualitative check of the filtering results



■ correct terrain pixels ■ omission errors ■ commission errors

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Advantages of the proposed method

- This technique is simple and requires no work tuning parameters except for *C* and *γ*.
- Effectively removes most of the non-ground points especially those on low vegetation.
- have the potential to solve high-dimensional data.

Future Work

we believe that with more work on enhancing the proposed technique, the scheme can form a new framework for automatic classification of the original lidar point clouds into terrain, low vegetation, trees, buildings and human-made objects.

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Thank you for your attention