



THREE-DIMENSIONAL TEXTURE IN THE CONTEXT OF REMOTE SENSING DAMAGE DETECTION

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ORDINARY GLCM-BASED TEXTURE FEATURES

Haralick, R. M., Shanmugam, K., Dinstein, I., Texture features for image classification, *IEEE Transactions on Systems, Man, and Cybernetics*, Vol 3, No. 6, 1973

0	0	2	1
0	0	2	2
0	2	2	2
2	2	3	3

$$P_H = \begin{pmatrix} 2 & 2 & 1 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 3 & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad P_V = \begin{pmatrix} 4 & 2 & 1 & 0 \\ 2 & 4 & 0 & 0 \\ 1 & 0 & 6 & 1 \\ 0 & 0 & 1 & 2 \end{pmatrix}$$

$$\text{Contrast} = \sum_{i,j=0}^{N-1} p_{ij} |i - j|^2$$

$$\text{Energy} = \sqrt{\text{ASM}}$$

$$\text{Dissimilarity} = \sum_{i,j=0}^{N-1} p_{ij} |i - j|$$

$$\text{Entropy} = - \sum_{i,j=0}^{N-1} p_{ij} \log(p_{ij})$$

$$\text{Homogeneity} = \sum_{i,j=0}^{N-1} \frac{p_{ij}}{1 + |i - j|^2}$$

$$\mu_i = \sum_{j=0}^{N-1} i p_{ij} \quad \mu_j = \sum_{i=0}^{N-1} j p_{ij}$$

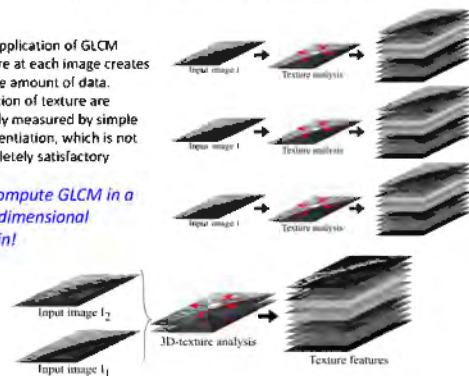
$$\text{ASM} = \sum_{i,j=0}^{N-1} p_{ij}^2$$

$$r = \sum_{i,j=0}^{N-1} p_{ij} \left| \frac{i - j}{\sqrt{\sigma_i^2 + \sigma_j^2}} \right|$$

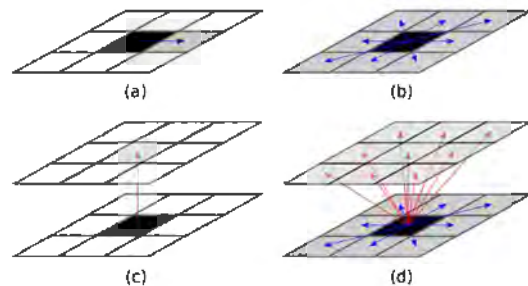
EARLY MOTIVATION OF THIS STUDY

- The application of GLCM texture at each image creates a huge amount of data.
- Variation of texture are usually measured by simple differentiation, which is not completely satisfactory

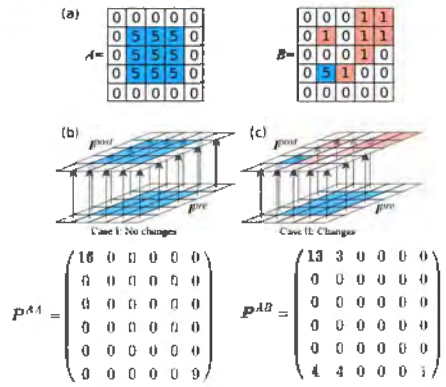
Lets compute GLCM in a three dimensional domain!



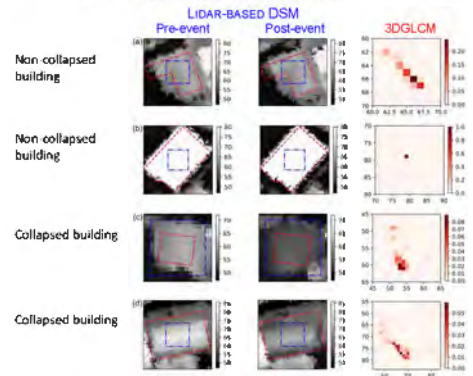
3DGLCM: EXTRAPOLATING IDEAS



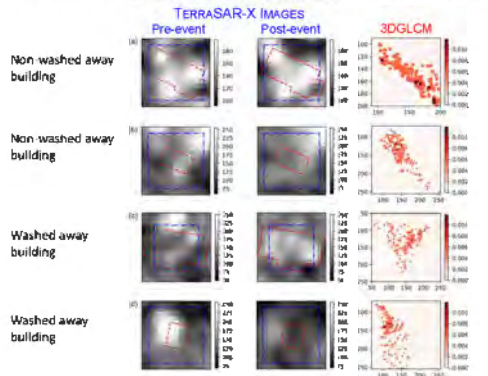
SOME INSIGHTS OF 3DGLCM APPLIED TO CHANGE DETECTION



SOME REAL EXAMPLES: THE 2016 KUMAMOTO EARTHQUAKE



SOME REAL EXAMPLES: THE 2011 TOHOKU EARTHQUAKE AND TSUNAMI



3DGLCM-BASED FEATURES

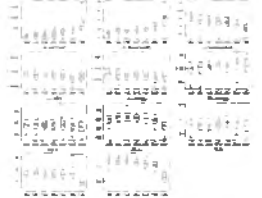
$$\text{Contrast} = \sum_{i,j=0}^{N-1} p_{ij} (i - j)^2$$

$$\text{ASM} = \sum_{i,j=0}^{N-1} p_{ij}^2$$

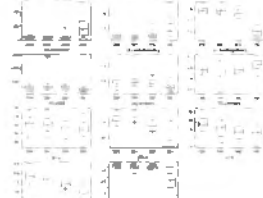
Feature	Samples from the TerraSAR-X				Samples from the Lidar data			
	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)
Contrast	163.30	422.90	2039.85	2314.00	0.27	0.00	31.15	79.64
Discrepancy	0.11	16.86	28.79	34.91	0.25	0.00	5.08	6.76
Homogeneity	0.13	0.05	0.62	0.05	0.89	1.00	0.11	0.02
ASM	0.01	0.01	0.01	0.01	0.15	1.00	0.04	0.03
Energy	0.06	0.06	0.06	0.03	0.37	1.00	0.20	0.17
Entropy	5.97	5.11	5.41	5.15	2.42	0.00	3.53	3.74
μ_1	151.46	147.95	150.47	151.05	16.16	74.00	57.78	74.36
μ_2	156.41	147.57	156.06	120.67	65.12	74.00	53.24	65.82
μ_3	23.13	36.74	20.07	43.05	1.56	0.20	3.73	1.79
μ_4	26.44	26.46	30.30	19.98	1.45	0.71	1.67	7.43
σ	0.26	0.03	0.00	0.51	0.45	0.40	0.40	0.00

PERFORMANCE CLASSIFICATION OF COLLAPSED BUILDINGS

The 2011 Tohoku Earthquake Tsunami



The 2016 Kumamoto Earthquake



Accuracy assessment of the final segmented DSM-complexion of collapsed building based on WGLCM based features and this region of interest (ROI) (building) samples with storage levels from 100 to 1000 were selected as non-collapse, while samples with storage levels 100 and 500 were labeled as collapse. The WGLCM were compared with random forest of $2 \times 2 \times 81 \times 17$ and $2 \times 2 \times 81 \times 17$ MC, respectively samples, C: Change/ sample, No: average.

Wavelet size	F1			Recall			Precision		
	M	L	A1	M	L	A1	M	L	A1
100	0.76	0.76	0.79	0.73	0.72	0.76	0.76	0.75	0.76
200	0.86	0.79	0.83	0.81	0.78	0.79	0.82	0.83	0.82
300	0.81	0.79	0.80	0.78	0.80	0.77	0.84	0.81	0.81
400	0.83	0.83	0.82	0.87	0.87	0.82	0.79	0.86	0.83
500	0.84	0.81	0.84	0.87	0.87	0.84	0.85	0.84	0.84

Accuracy assessment of DSM-based WGLCM-based features using 3D DSM-complexion. The matrix is reported from all WGLCM-based with the dataset provided by <http://www.3dgeo.com> is reported as a feature of 1000 MC. Non-collapse: 0, collapse: 1, collapsed: 0, average.

Wavelet size	F1			Recall			Precision		
	M	L	A1	M	L	A1	M	L	A1
100	0.80	0.80	0.87	0.80	0.80	0.87	0.87	0.86	0.87
200	0.83	0.84	0.88	0.86	0.83	0.81	0.81	0.81	0.82
300	0.84	0.81	0.81	0.81	0.81	0.80	0.80	0.80	0.81
400	0.83	0.83	0.81	0.83	0.83	0.81	0.81	0.81	0.82
500	0.81	0.81	0.85	0.85	0.82	0.84	0.84	0.84	0.84

THANK YOU VERY MUCH

Find more details in our paper (open access!):

Moya, L., Zakeri, H., Yamazaki, F., Liu, W., Mas, E., Koshimura, S., 3D gray level co-occurrence matrix and its application to identifying collapsed buildings, *ISPRS Journal of Photogrammetry and Remote Sensing*, Volume 149, 2019.

