Thesis review

Time Series Change Detection Algorithms for Land Cover Change

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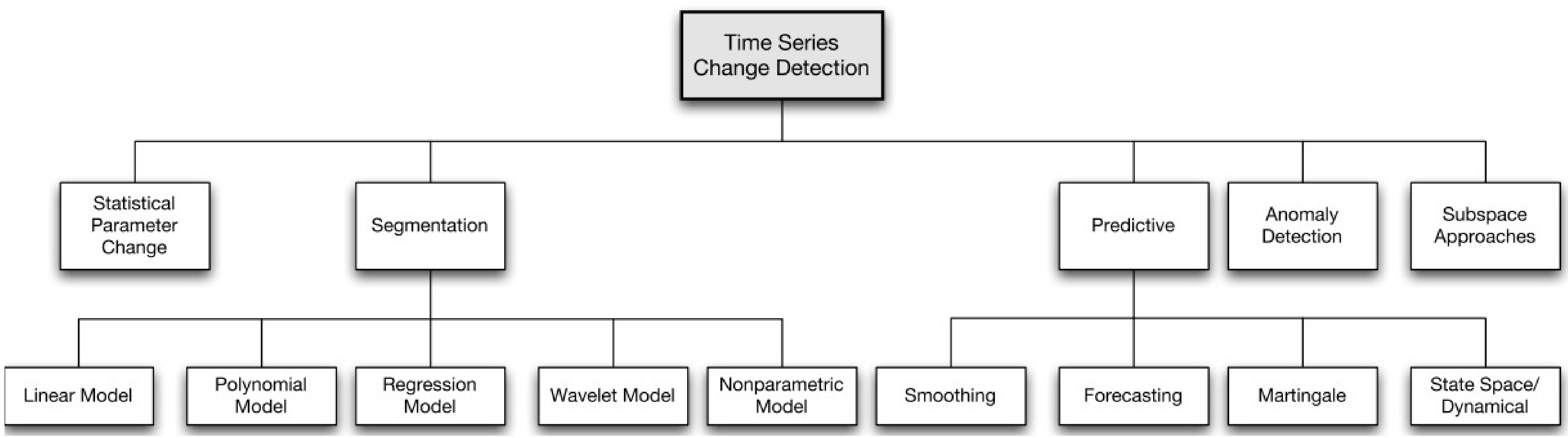
Taxonomy


Time Series Change Detection
Statistical Parameter Change
Segmentation
Predictive
Anomaly Detection
Subspace Approaches
Linear Model
Polynomial Model
Regression Model
Wavelet Model
Nonparametric Model
Smoothing
Forecasting
Martingale
State Space/ Dynamical

Statistical Parameter Change

- Data follows a parametric distribution
- Methods detect points where a distribution parameter change
- Estimate the value of the parameters before and after the change

Segmentation

- Partition the input time series into homogeneous segments
- When successive segments are not homogenous, there is a change point between them

Predictive

- Methods are based on the assumption that one can learn a model for a portion of the input time series
- Change is detected based on deviation from the model

Anomaly Detection

- Methods find regions of a time series that are significantly different from the rest of the time series
- Anomaly detection is looking for a temporary departure from normal

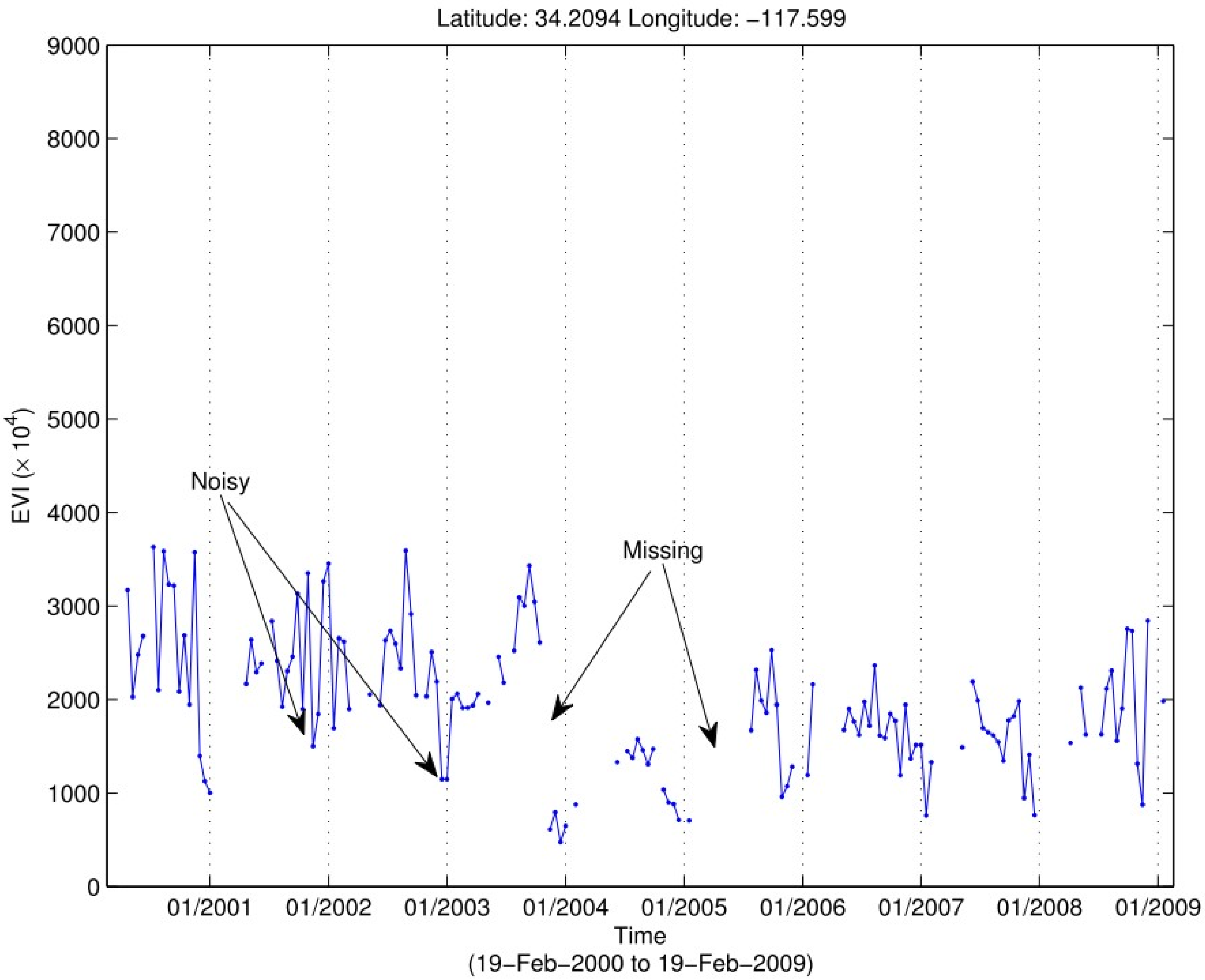
Subspace

- Methods encode the input time series into a matrix structure
- Employ spectral methods (*e.g.* PCA) and look for changes in the matrix structure

Change Detection Challenges

- Massive data size
- High degree of geographic/inter-region variation
- Noisy/missing data
- Disparate land cover types
- Wide variety of changes that can occur

Common Problem



Time Series x Snapshot Model

- Time series based change detection has significant advantages over the comparison of snapshot images of selected dates because it takes into account information about the temporal dynamics of landscape changes

Revision - Lunetta et. al.

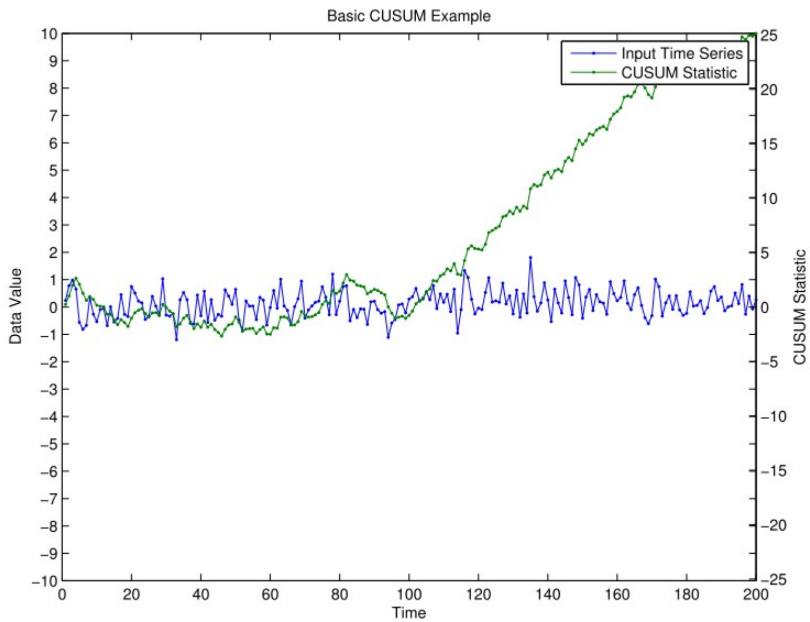
- Begins by computing annual sums, and differences between consecutive years
- Resulting differences are assumed to follow normal distribution ($\mu = 0$, no change)
- The z-score of the difference of annual sums is computed
- If the z-score is above a threshold τ,a change is considered to have occurred between t_1 and t_2

Revision - Cummulative SUM

- Given a time series $\{t_1, t_2, \ldots\}$ and an in-control mean μ, the statistic is defined as

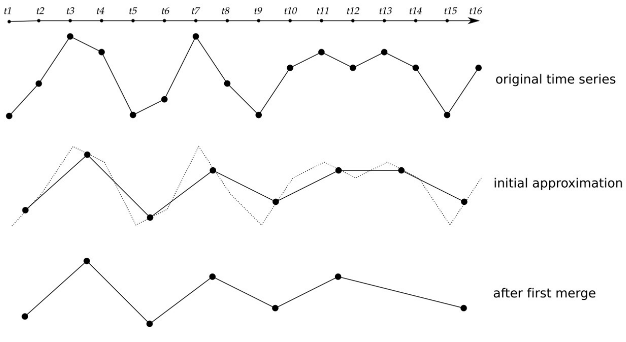
$$CS_k = \sum_{i=0}^{\kappa} (t_i - \mu).$$

The basic algorithm sets μ to an apriori known value, or to the first value t1 of the time series



Recursive Merging

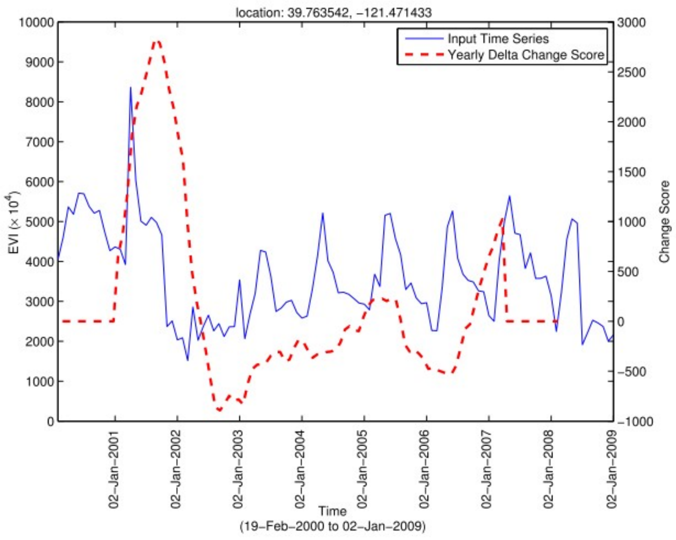
- A given time series can be partitioned into homogeneous segments
- Boundaries between segments are changes
- Two most similar consecutive annual cycles are merged until one annual cycle is left remaining
- Change score for this location is based on the dimension of the observed cycle distances



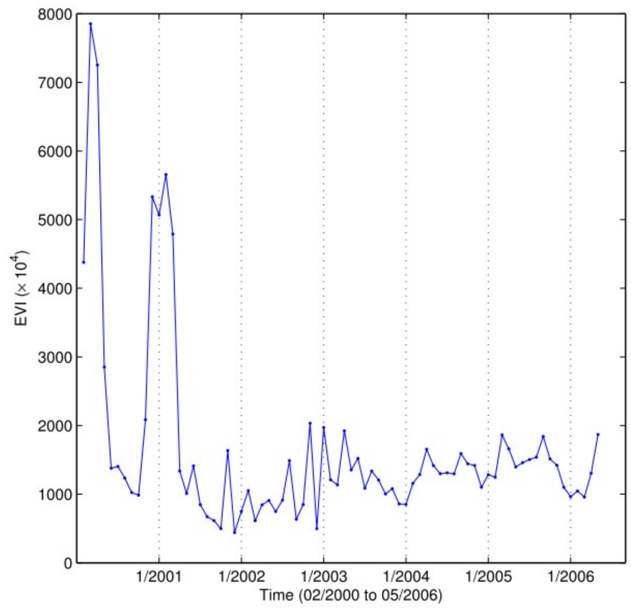
Yearly Delta

- The method Looks for discrepant sequences in relation to a model of previous observations in the time series

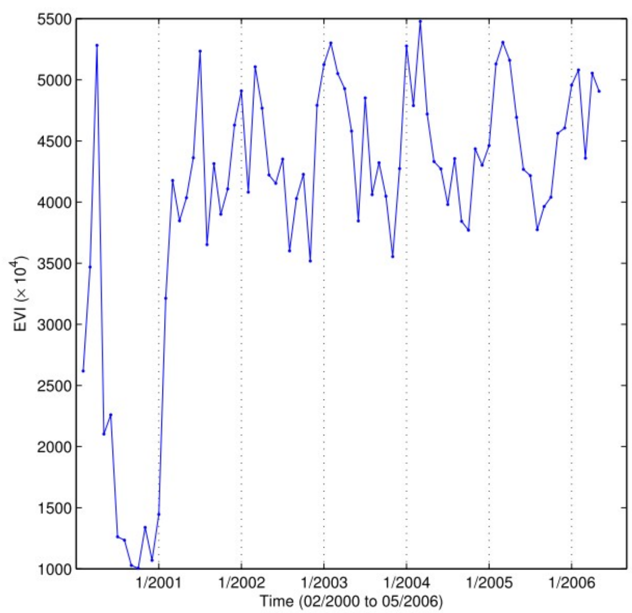
1. Build an initial projection model based on a short window at the beginning of the time series
2. Compare subsequent windows to the model's
3. Grow the model by incorporating subsequent values



Applications



Source: Google Maps.



Source: Google Maps.

Results - Comparison

Year	Polygon Size	RM0	YD0	LUNETTA_NO_NORM	CUSUM_MEAN
2000	111	54	10	24	12
2001	1142	814	943	796	1009
2002	2407	1383	2238	2197	2164
2003	4946	3609	4258	3512	4338
2004	661	423	571	412	521
2005	192	96	136	100	134
2006	278	146	187	157	152
2007	1935	1413	1669	1332	1360
2008	6778	5312	4078	4556	490
SUM	18450	13250	14090	13086	10180
p_n	1.00	0.72	0.76	0.71	0.55

$$p_n = \frac{TP_n}{TP_n + FP_n}$$

Results - Missing Data

Year	Polygon Size	RM0_MISSING	YD0_MISSING	CUSUM0_MISSING
2000	1379	630	476	234
2001	6827	4154	5189	4593
2002	12092	7541	9047	7977
2003	12292	8423	9763	8207
2004	4218	3078	3600	3011
2005	744	377	446	280
2006	6165	4076	4689	2072
2007	10666	8923	9683	3316
2008	27901	17622	13961	2758
SUM	82284	54824	56854	32448
p_n	1.00	0.67	0.69	0.39

Results - Full Dataset

Year	Polygon Size	RM0	YD0	LUNETTA_NO_NORM	CUSUM_MEAN
2000	1379	458	294	431	443
2001	6827	3661	4757	3648	5520
2002	12114	7061	8284	7310	9335
2003	12292	8514	9058	6852	9915
2004	4218	2786	3452	3056	3152
2005	744	293	386	259	336
2006	6165	3900	4235	3296	3948
2007	10671	9285	9177	8459	6736
2008	27901	17581	11013	14890	1742
SUM	82311	53539	50656	48201	41127
p_n	1.00	0.65	0.62	0.59	0.50

Conclusions

- Recursive merging algorithm performed consistently well across three data sets with different levels of noise and missing data
- Yearly delta scheme is specifically meant for detecting reduction in vegetation, it performs the best amongst all algorithms for detecting fires

Conclusions

- Cummulative Sum is primarily geared towards detecting changes in one direction, and is good to detect both small and gradual shifts
- Lunetta *et. al.* approach detects changes in both directions, and is the only algorithm to directly incorporate space into the change detection

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