Change Detection Algorithm with Hardware Constraints

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Change Detection on Embedded Systems

1. **Monomodal, multimodal (fusion), supervised, unsupervised** → rapid data analysis, low computational complexity and power consumption, memory requirements[1]
2. **Time-series methods**[3] → ARIMA, PCA, SVM, Random Forest, NN, K-means, GLM, EM, SVD, XGboost, LSTM,..
3. **Parallelism** → Distributed data processing architectures for runtime, memory and energy saving[2]

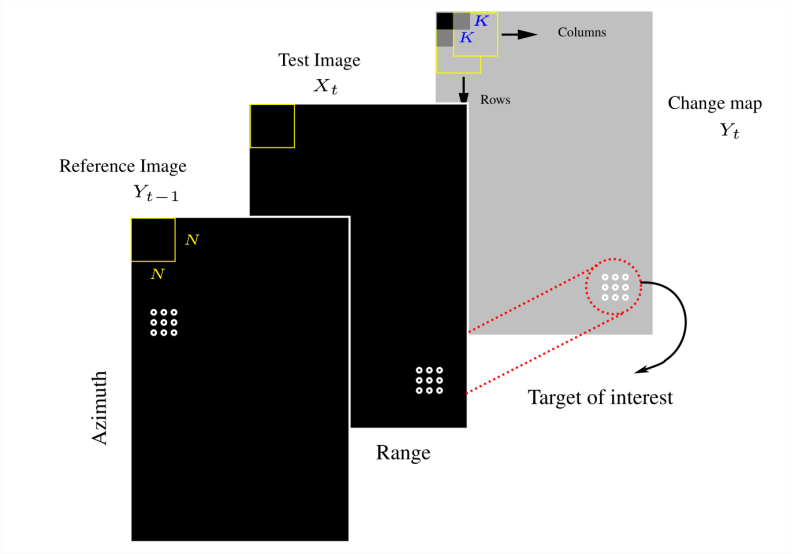
[1] Wu, Suya, et al. "Quickest Change Detection for Unnormalized Statistical Models," *IEEE Trans. on Inf. Theory*, v. 70, n. 2, pp. 1220-1232, 2024.

[2] Rabhi *et al.*, "Patterns and skeletons for parallel and distributed computing," Springer Science & Business Media, 2003.

[3] Bayer, F.M., *et al.*, "A Novel Rayleigh Dynamical Model for Remote Sensing Data Interpretation," *IEEE Trans. on Geoscience and Remote Sensing*, v. 58, n. 7, pp. 4989-4999, 2020.

Time series Prediction Model

$$\hat{Y}_t = f(X_t, Y_{t-1}, Y_{t-2}, \ldots, Y_{t-p}) + \epsilon_t, \quad (1)$$



Combinational solution

X_t	Y_{t-1}	Change
0	0	No change
0	1	No change
1	0	Change
1	1	No change

Note: Anomaly = 1, background = 0.

Auto-regressive first order Model (AR(1)): Detects uncorrelated samples between $y_{t-1}[n, m]$ and $x_t[n, m]$ as a predicted anomaly to compose the change map $y_t[n, m]$, which describes the degree of retained memory of previous states.

$$\underbrace{\hat{y}_t[n, m]}_{\text{changes}} = \underbrace{\rho}_{\text{corr.}} \underbrace{y_{t-1}[n, m]}_{\text{ref. signal}} + \sqrt{1 - \rho^2} \underbrace{x_t[n, m]}_{\text{test signal}}, \tag{2}$$

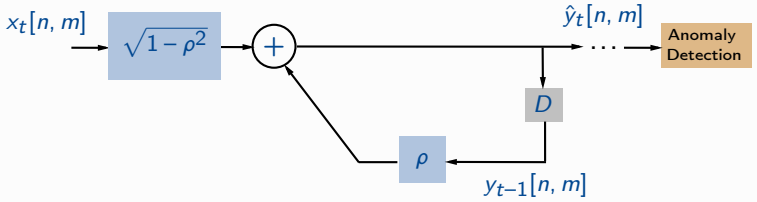


Figure: The stationary fisrt-order AR structure

VHF-UWB SAR Dataset: CARABAS-II

CARABAS-II dataset[4]:

Original data: 2 × 3 km (100%)

- 24 images: magnitude SAR HH-polarized VHF (20-90 MHz), 1 m resolution.
- 4 Targets position: S1 (2), K1 (3), F1 (4), and AF1 (5)
- 6 Passes: Flight direction and RFI sources (on/off)
- Application: Detection under Foliage Penetration.

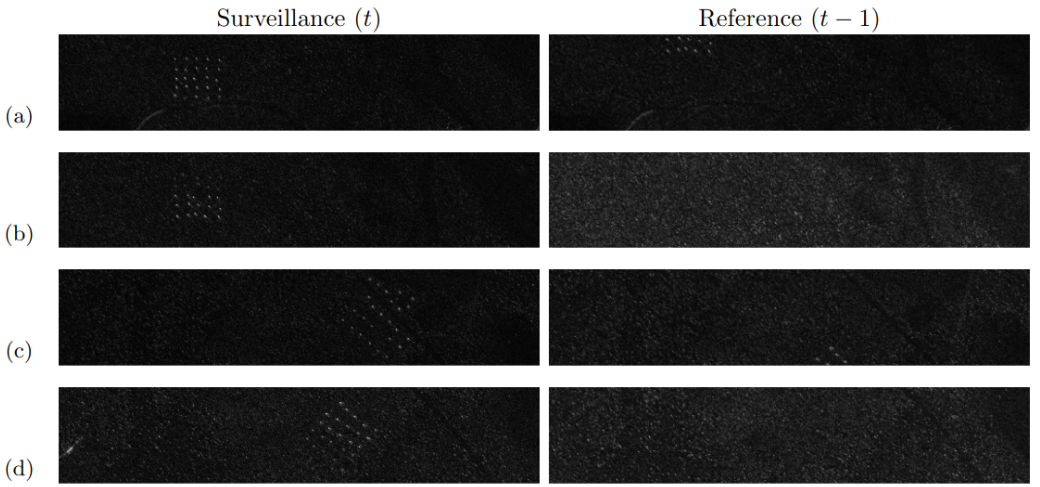
[4]Ulander, L.M, et al. "Change detection for low-frequency sar ground surveillance," *IEE Proceedings-Radar, Sonar and Navigation* , 152(6), pp. 413–420, 2005.

VHF-UWB SAR Dataset: CARABAS-II

Exp. No.	Surveillance image		Reference image		Known Targets	Area [km^2]
	Mission	Pass	Mission	Pass		
1	2	1	3	1	25	6
2	3	1	4	1	25	6
3	4	1	5	1	25	6
4	5	1	2	1	25	6
5	2	2	4	2	25	6
6	3	2	5	2	25	6
7	4	2	2	2	25	6
8	5	2	3	2	25	6
9	2	3	5	3	25	6
10	3	3	2	3	25	6
11	4	3	3	3	25	6
12	5	3	4	3	25	6
13	2	4	3	4	25	6
14	3	4	4	4	25	6
15	4	4	5	4	25	6
16	5	4	2	4	25	6
17	2	5	4	5	25	6
18	3	5	5	5	25	6
19	4	5	2	5	25	6
20	5	5	3	5	25	6
21	2	6	5	6	25	6
22	3	6	2	6	25	6
23	4	6	3	6	25	6
24	5	6	4	6	25	6
Total					600	144

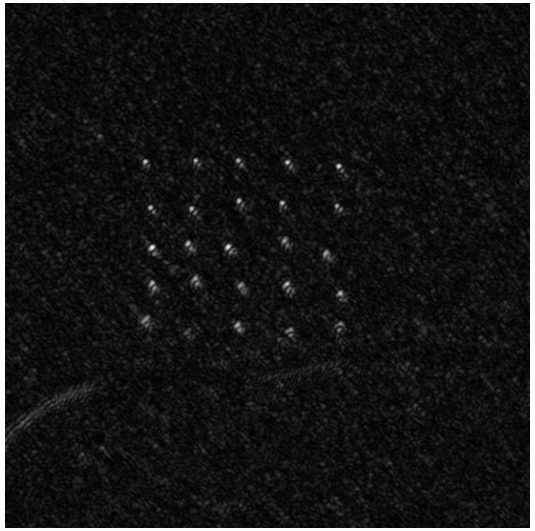
Include all lags y(t-n) to improve the prediction model

Campaign sample data: 2×0.5 km (15%)

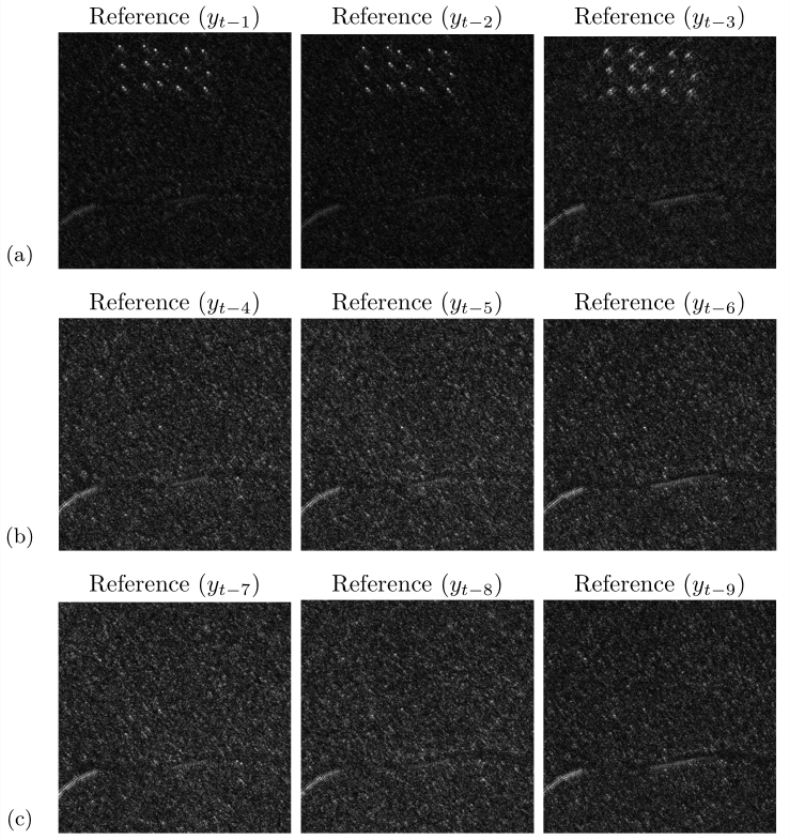


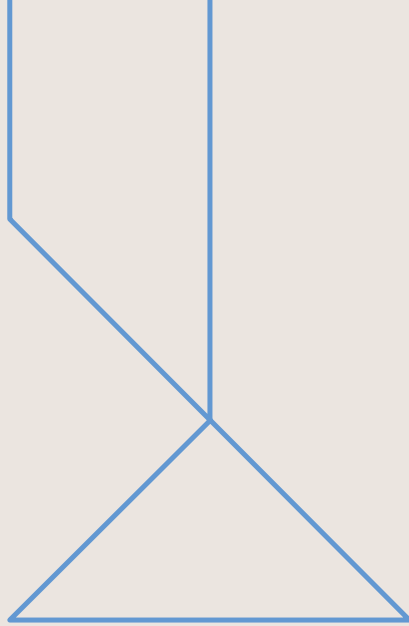
VHF-UWB SAR Dataset: CARABAS-II

Surveillance x_t



Statistical sample data: 0.5×0.5 km (4%)





Demo 1: Simple processing on ForSyde/Haskell

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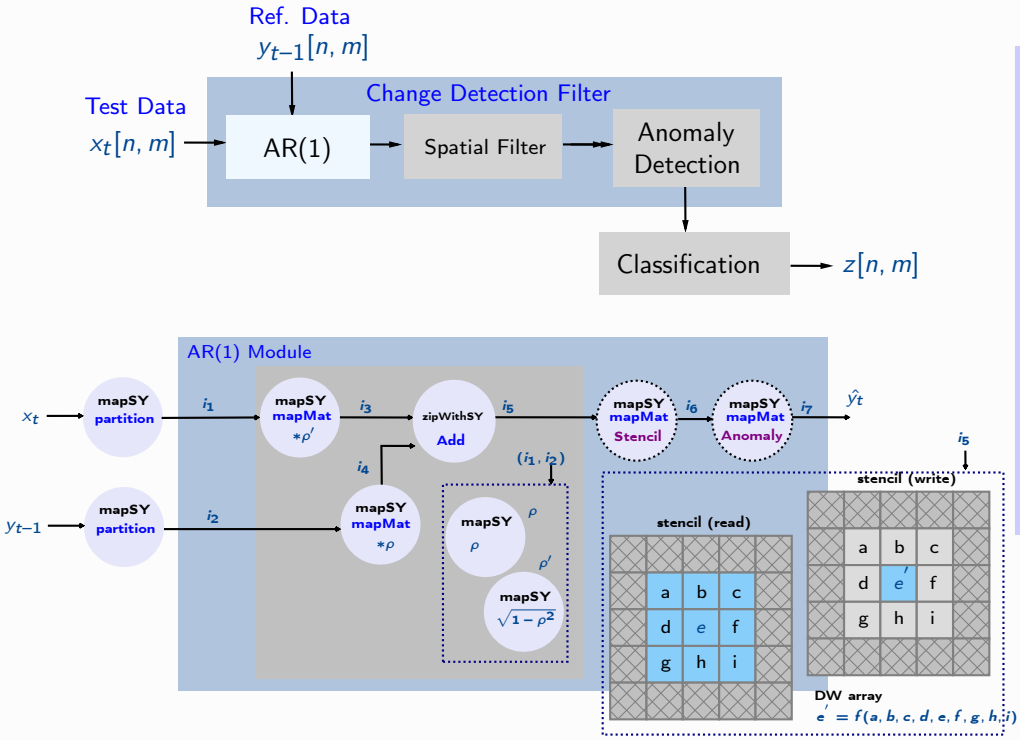
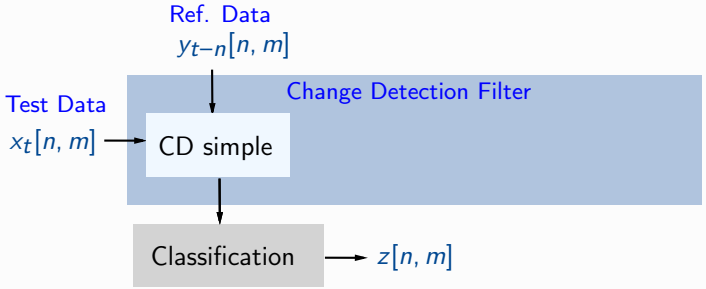
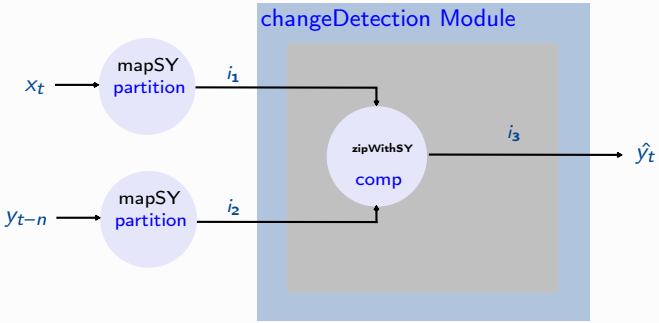


▶Files

- changeDetection.hs
- classifier.py
- Itesti.dat (500×500) (i=Exp.No.)
- Irefin.dat (500×500) (n=lags)
- .mat (known targets position)

Demo 1: Simple processing on ForSyde/Haskell



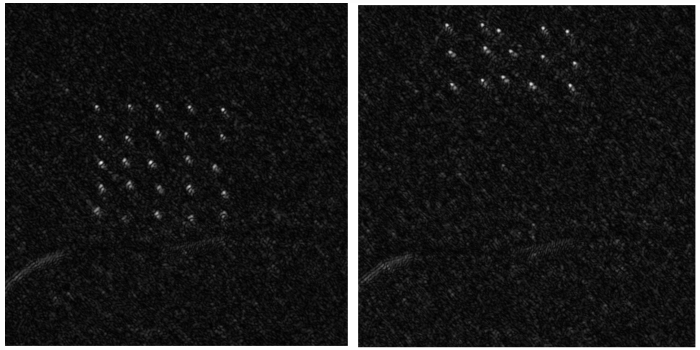


▶Files

- changeDetection.hs
- classifier.py
- Itest0.dat (500 × 500) (i=0)
- Iref0A.dat (500 × 500) (n=A)
- S1.mat (known targets position)

Demo 1: Simple processing on ForSyde/Haskell

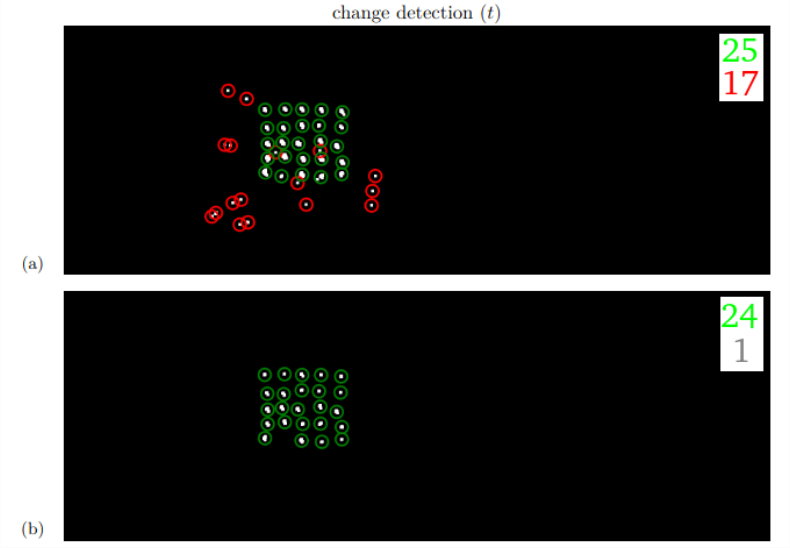
Surveillance (t) and Reference $(t-1)$



Objectives:

- Extend to n-lags with parallelism
- HW/Detection optimization

Classification Results:



(a) threshold = 0.45, (b) threshold = 0.7

Project's Schedule

Project's Schedule

Period	Main Activities
11 Sep. 2024	• Dataset → VHF-UWB SAR (CARABAS-II system) change detection challenger. • Demo 1 → simple processing on ForSyDe/Haskell.
16 Sep. 2024	• AR(n) model → Model construction on ForSyDe/Haskell. • Demo 2 → lags test. • Distributed Parallelism → project objective.
TBD	• Demo 3 → Validation campaign: Receiver operating characteristic (ROC), power consumption, memory, FLOPs, runtime.
TBD	• HW implementation and tests.
TBD	• Project Presentation.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