Détection d'anomalies en SAR basée sur les réseaux génératifs

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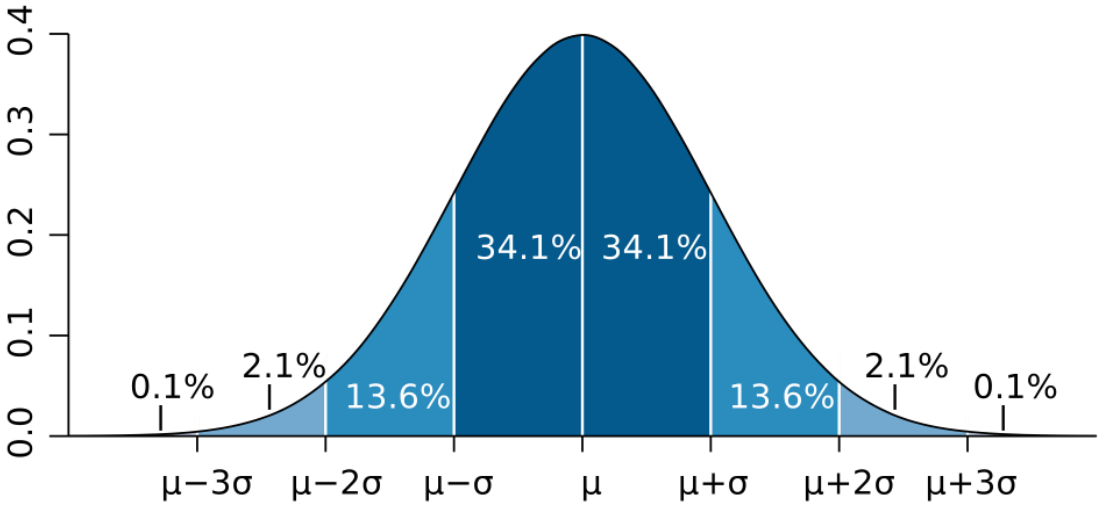
What is an anomaly ?

Context

What is normality ?

What considerably deviates from it ?

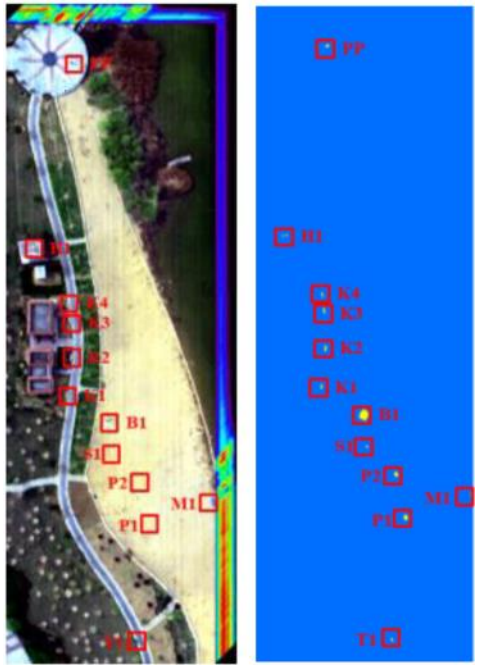
- Point anomaly
- Group anomaly
- Contextual anomaly



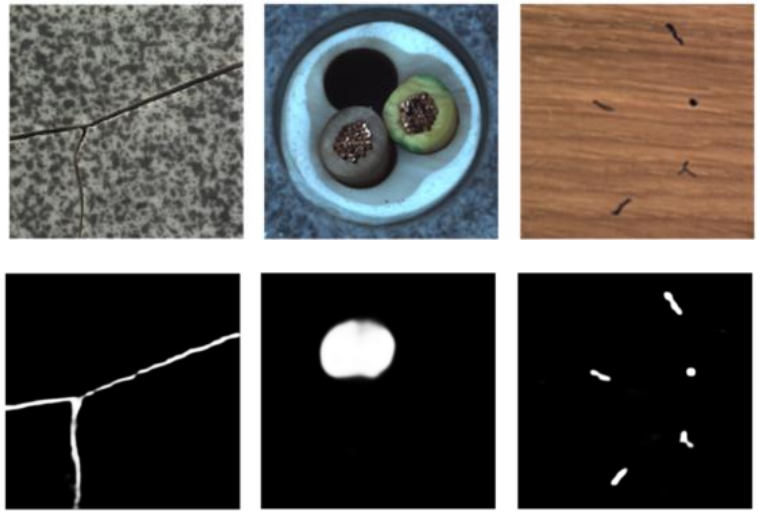
Wikipedia – Normal distribution

What is an anomaly ?

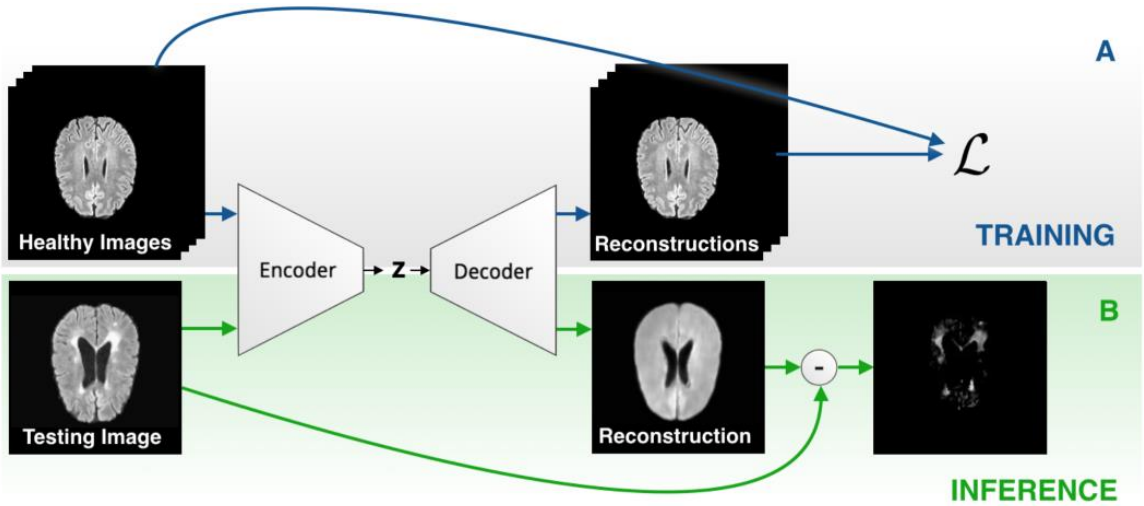
Examples



S. Wang, X. Wang, L. Zhang and Y. Zhong, "Deep Low-Rank Prior for Hyperspectral Anomaly Detection," in IEEE Transactions on Geoscience and Remote Sensing, vol. 60, pp. 1-17, 2022, Art no. 5527017, doi: 10.1109/TGRS.2022.3165833.



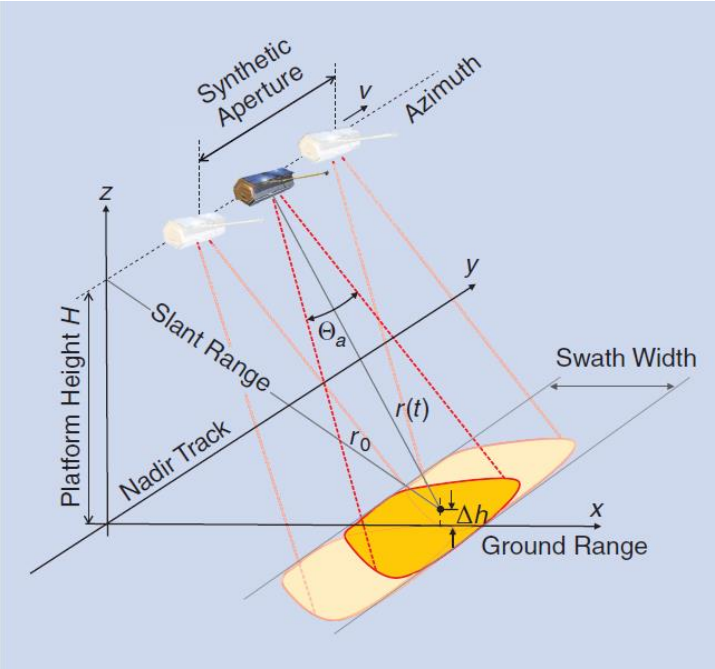
Song, Jouwon & Kong, Kyeongbo & Park, Ye-In & Kim, Seong-Gyun & Kang, Suk-Ju. (2021). AnoSeg: Anomaly Segmentation Network Using Self-Supervised Learning.

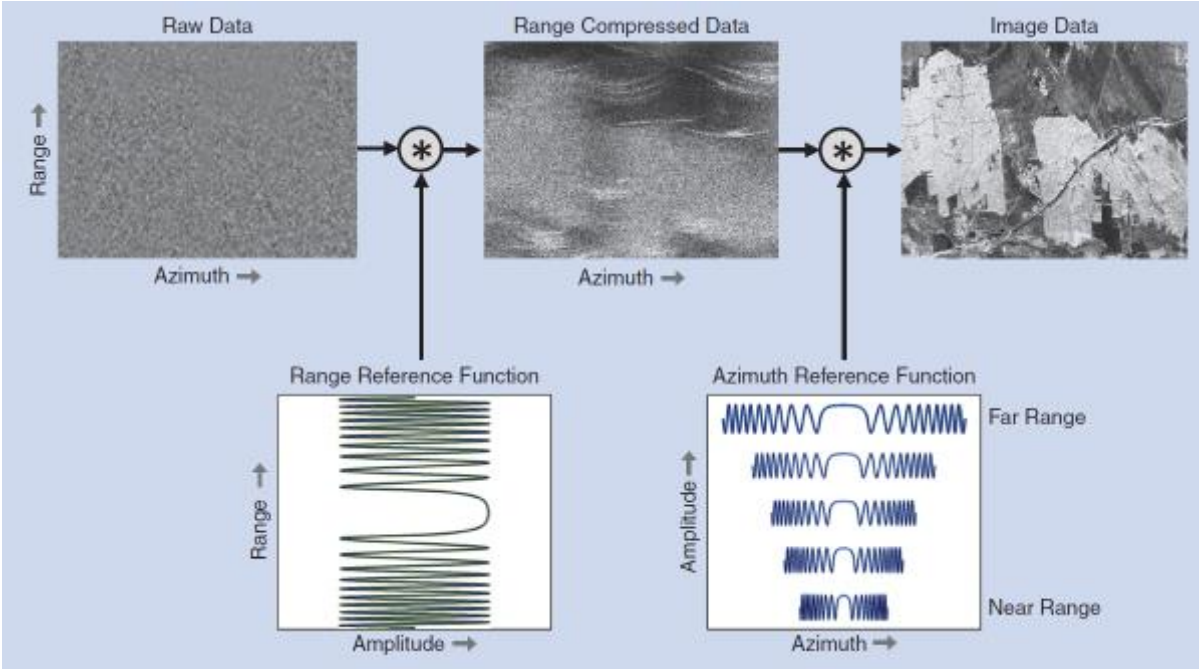


Baur, Christoph & Denner, Stefan & Wiestler, Benedikt & Albarqouni, Shadi & Navab, Nassir. (2020). Autoencoders for Unsupervised Anomaly Segmentation in Brain MR Images: A Comparative Study.

Synthetic aperture radar (SAR)

Acquisition

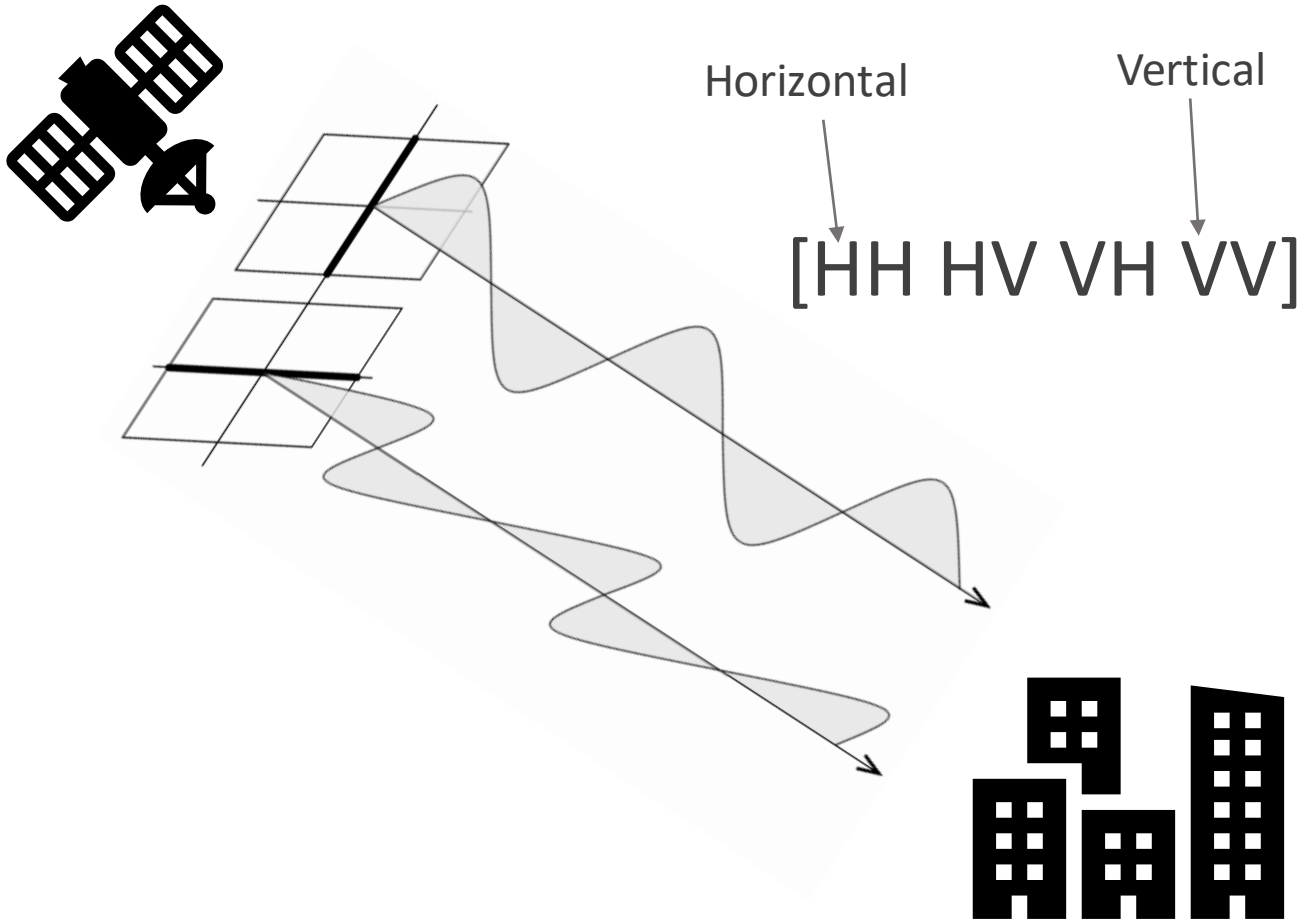


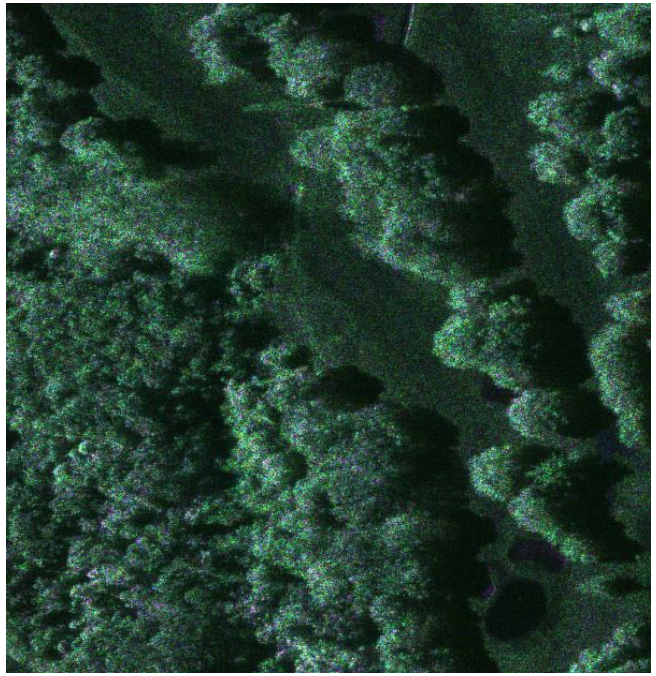


A. Moreira, P. Prats-Iraola, M. Younis, G. Krieger, I. Hajnsek and K. P. Papathanassiou, "A tutorial on synthetic aperture radar," in IEEE Geoscience and Remote Sensing Magazine, vol. 1, no. 1, pp. 6-43, March 2013, doi: 10.1109/MGRS.2013.2248301.

Synthetic aperture radar (SAR)

Polarimetry





Synthetic aperture radar (SAR)

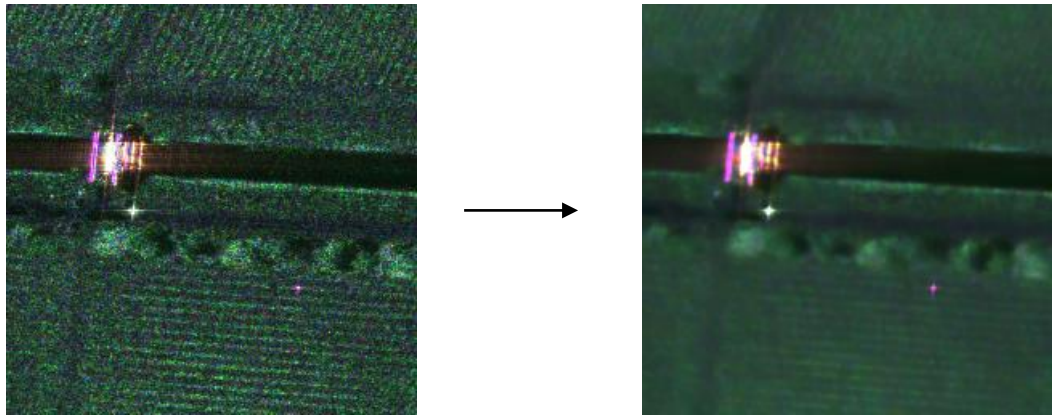
Speckle

$$I = R \times S$$

Intensity Reflectivity Speckle

$$p_I(I|R) = \frac{L^L I^{L-1}}{\Gamma(L) R^L} \exp\left(-L\frac{I}{R}\right)$$

- Increase the probability of false alarm (PFA)



Standard statistical aproach

Mahalanobis distance

$$d(x) = \sqrt{(x-\mu)^H \Sigma^{-1} (x-\mu)}$$

$$\hat{\boldsymbol{\Sigma}} = \frac{1}{N-1} \sum_{i=1}^{N} \left(x_i - \hat{\boldsymbol{\mu}}\right)\left(x_i - \hat{\boldsymbol{\mu}}\right)^H, \quad \hat{\boldsymbol{\mu}} = \frac{1}{N} \sum_{i=1}^{N} x_i \,.$$

- x should follow a normal multivatiate distribution
- Not robust to outliers
- Detects edges

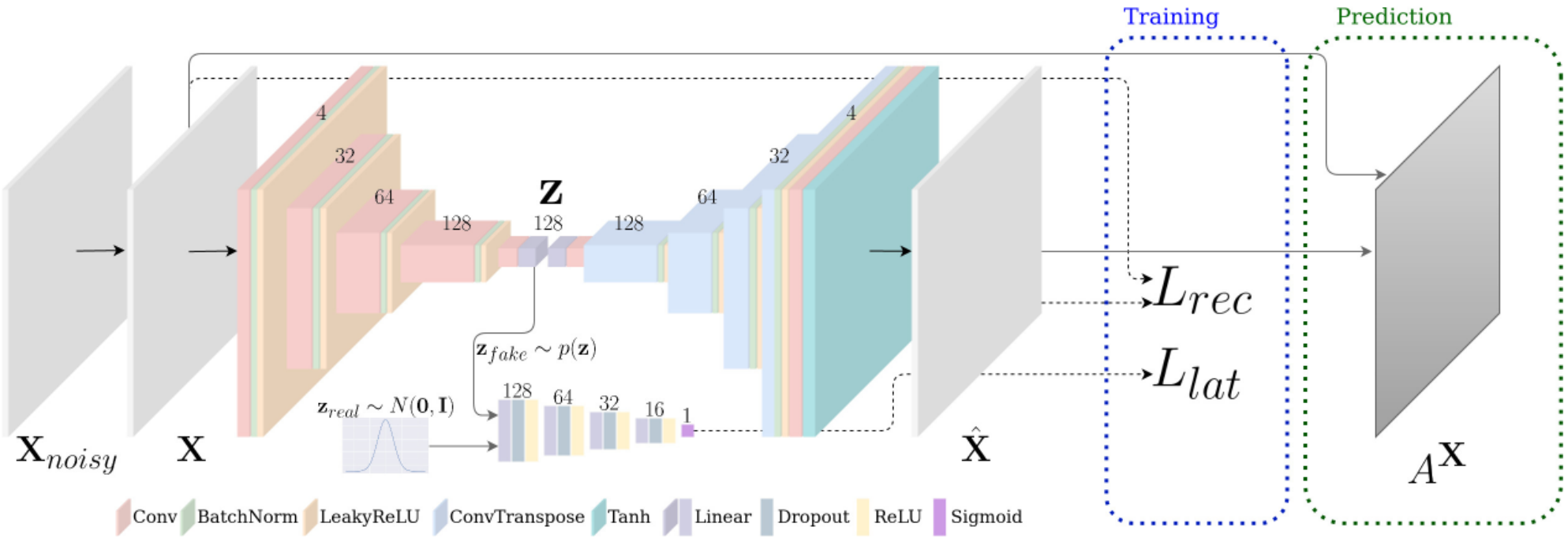
Proposed SAR anomaly detection

Overwiew

- Deep learning framework combined with a change detection method
- Self-supervised training
- No label
- No a priori

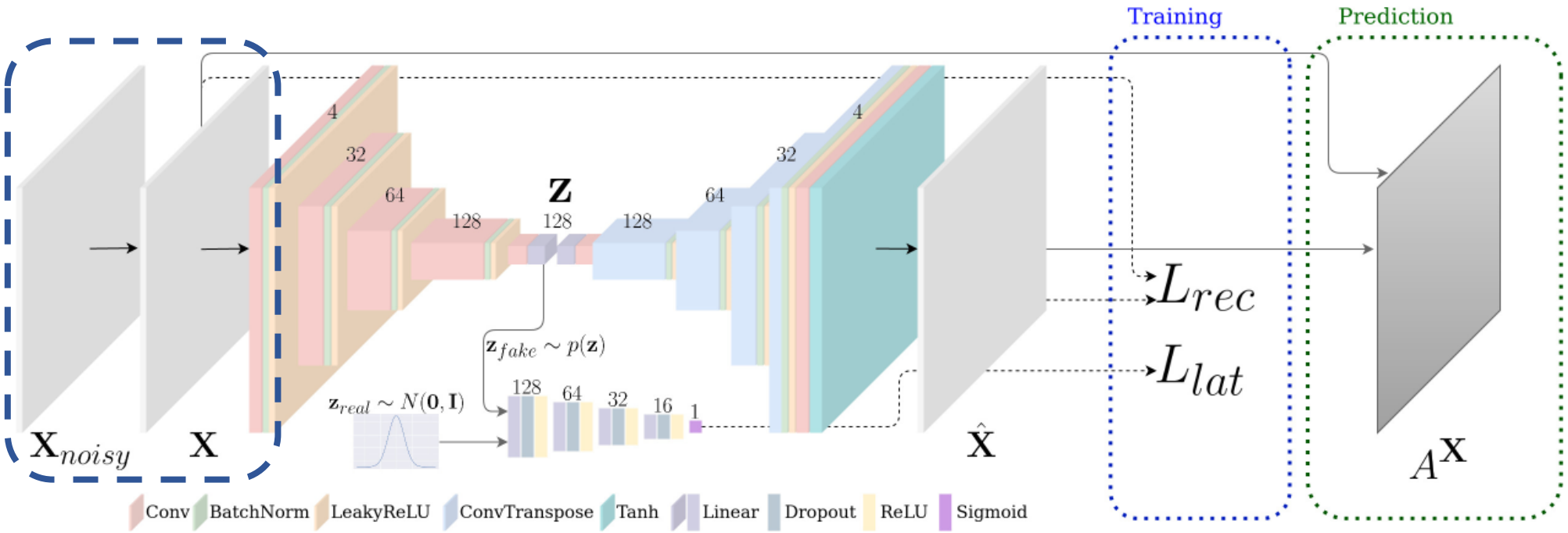
Proposed SAR anomaly detection

Overwiew



Proposed SAR anomaly detection

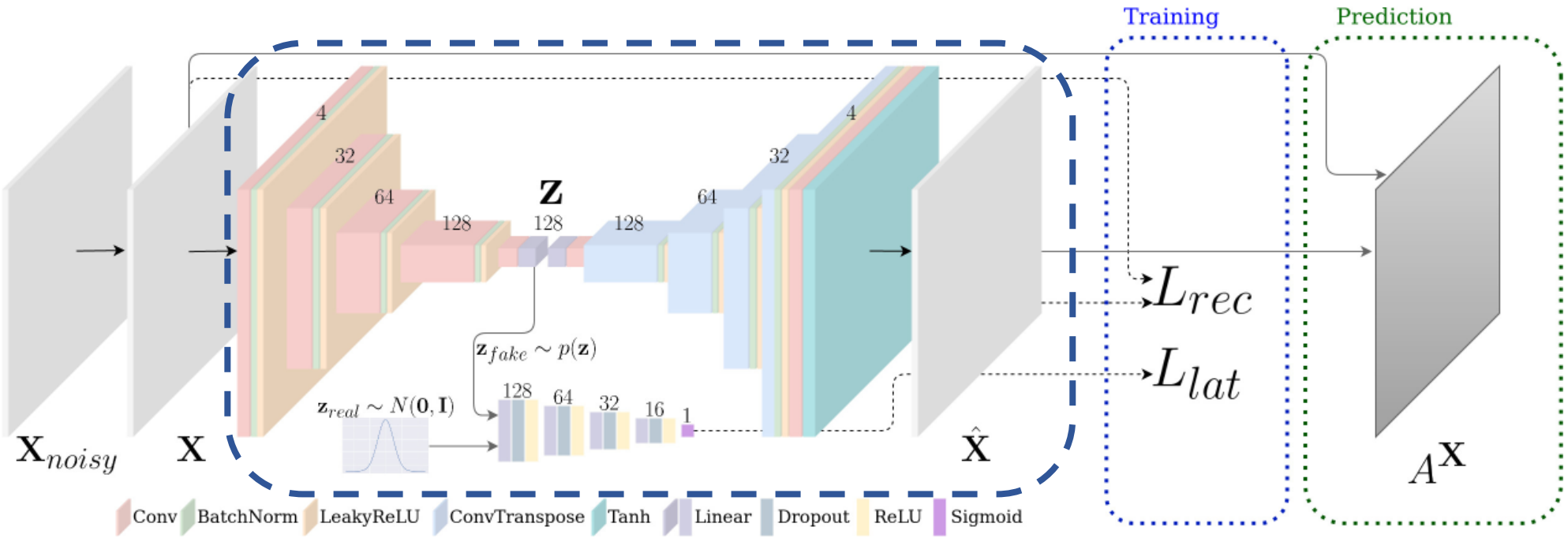
Overwiew



Despeckling

Proposed SAR anomaly detection

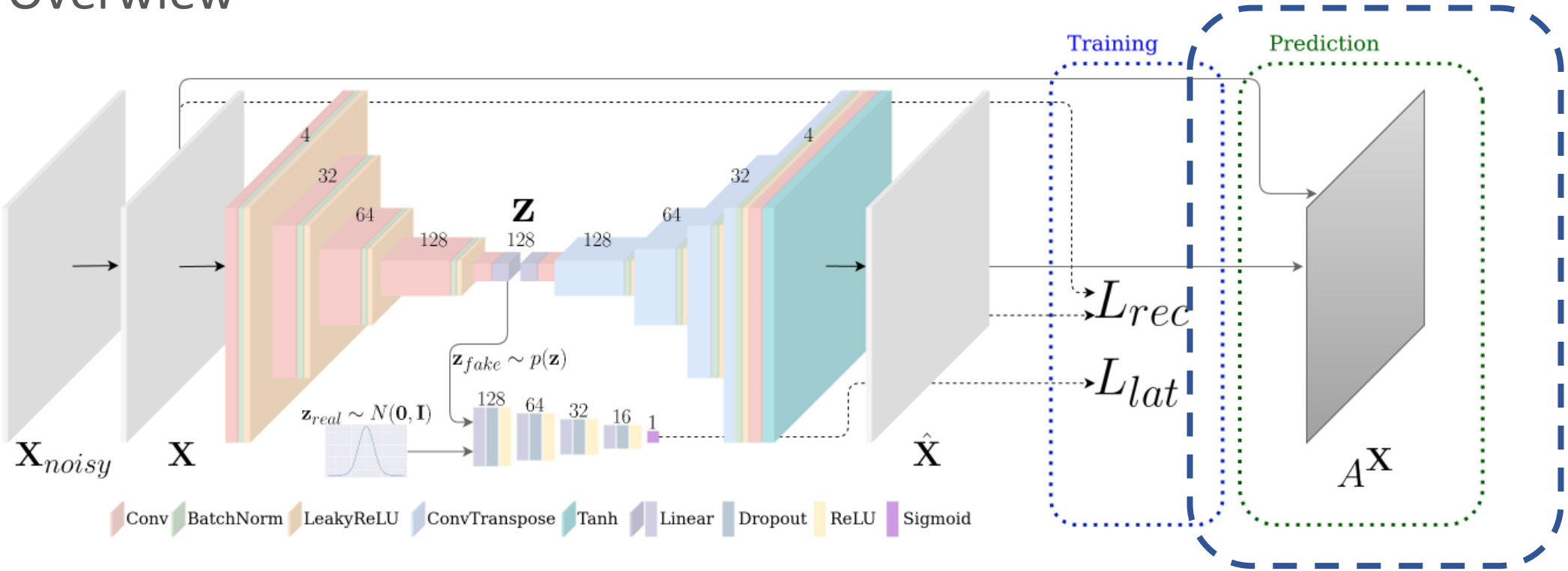
Overwiew



Despeckling → AAE

Proposed SAR anomaly detection

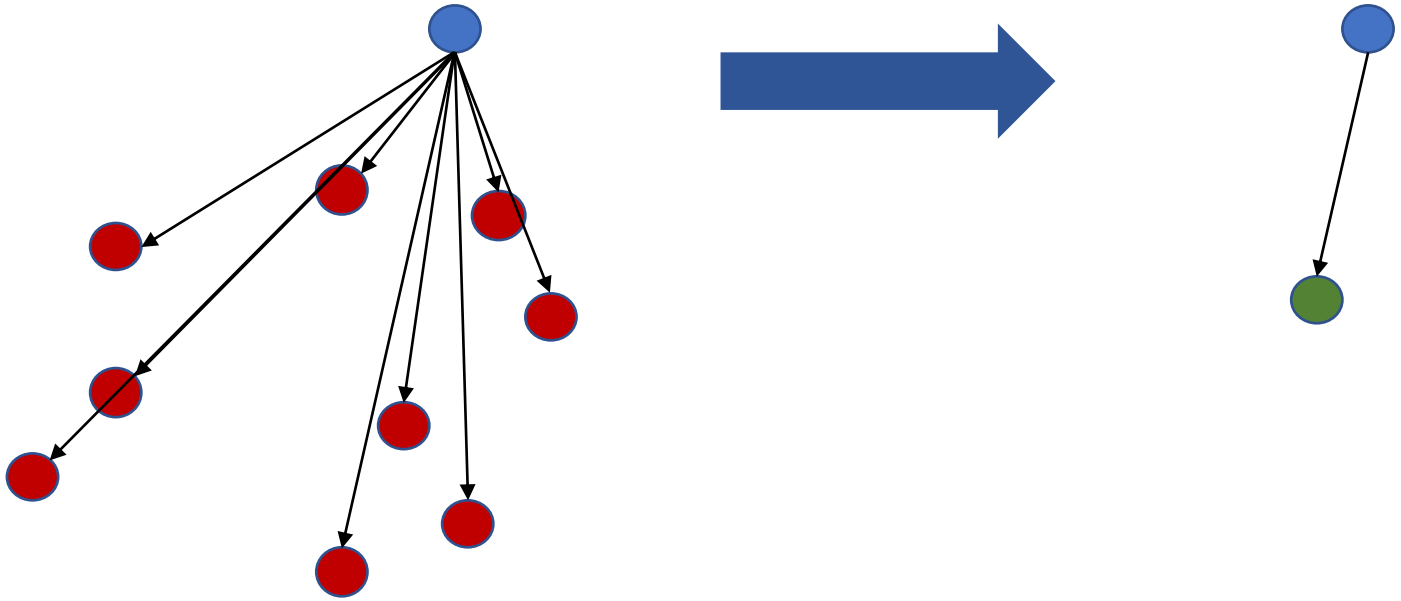
Overwiew



Despeckling → AAE → Change detection

Proposed SAR anomaly detection

Despeckling



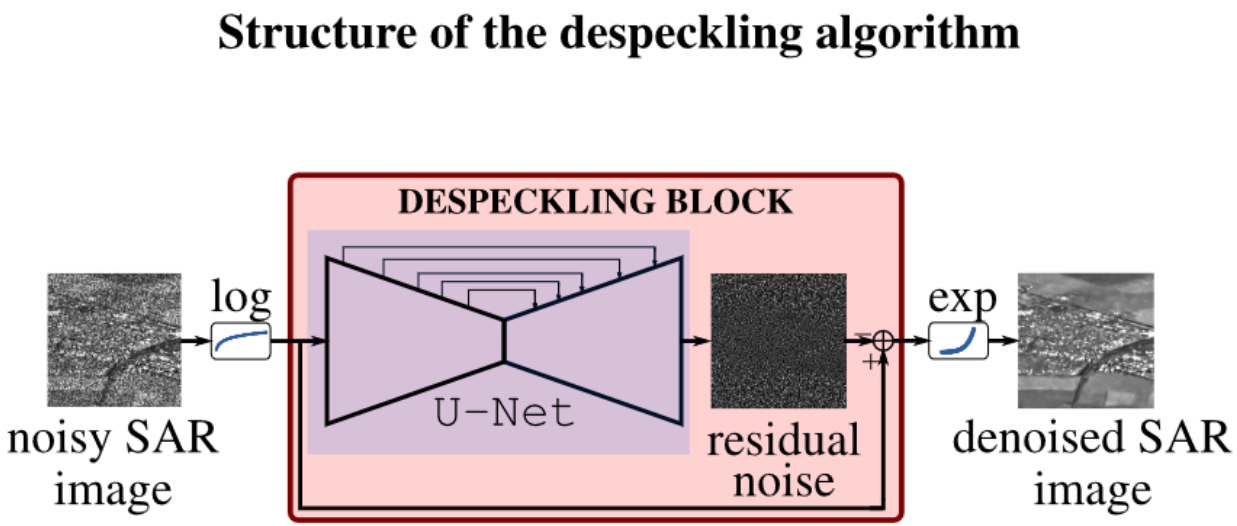
$$\underset{z}{\operatorname{argmin}}\, \mathbb{E}_y\{L(z,\, y)\}$$

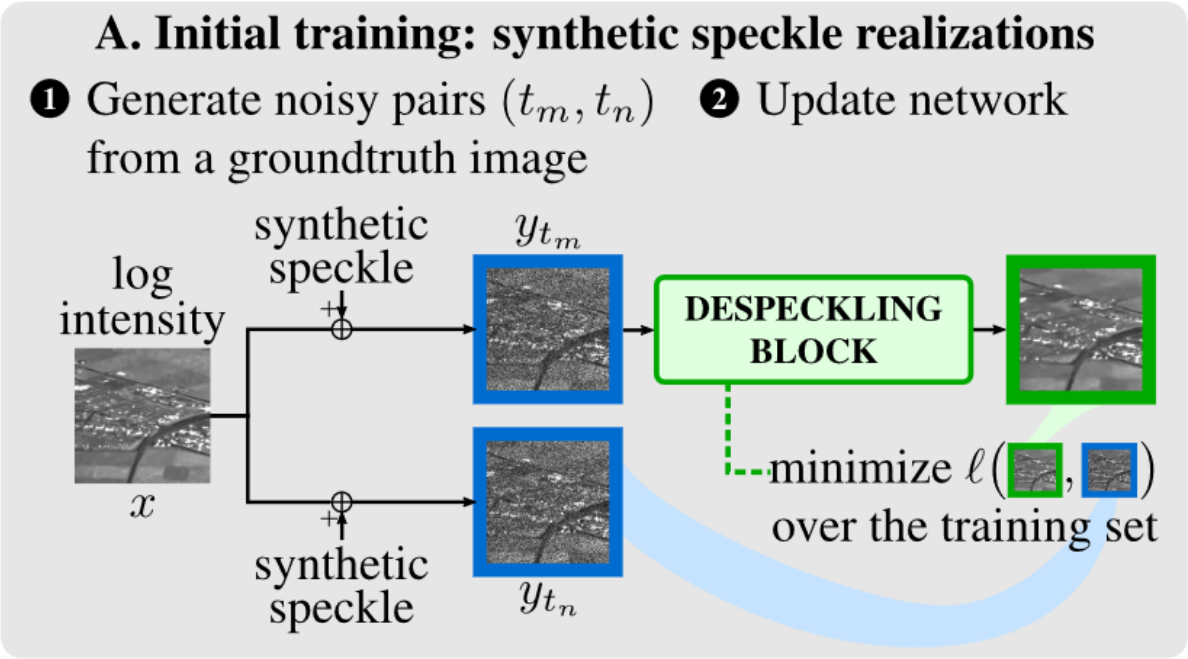
$$z = \mathbb{E}_y\{y\}$$

J. Lehtinen, J. Munkberg, J. Hasselgren, S. Laine, T. Karras, M. Aittala, and T. Aila, "Noise2noise : Learning image restoration without clean data," 2018.

Proposed SAR anomaly detection

Despeckling

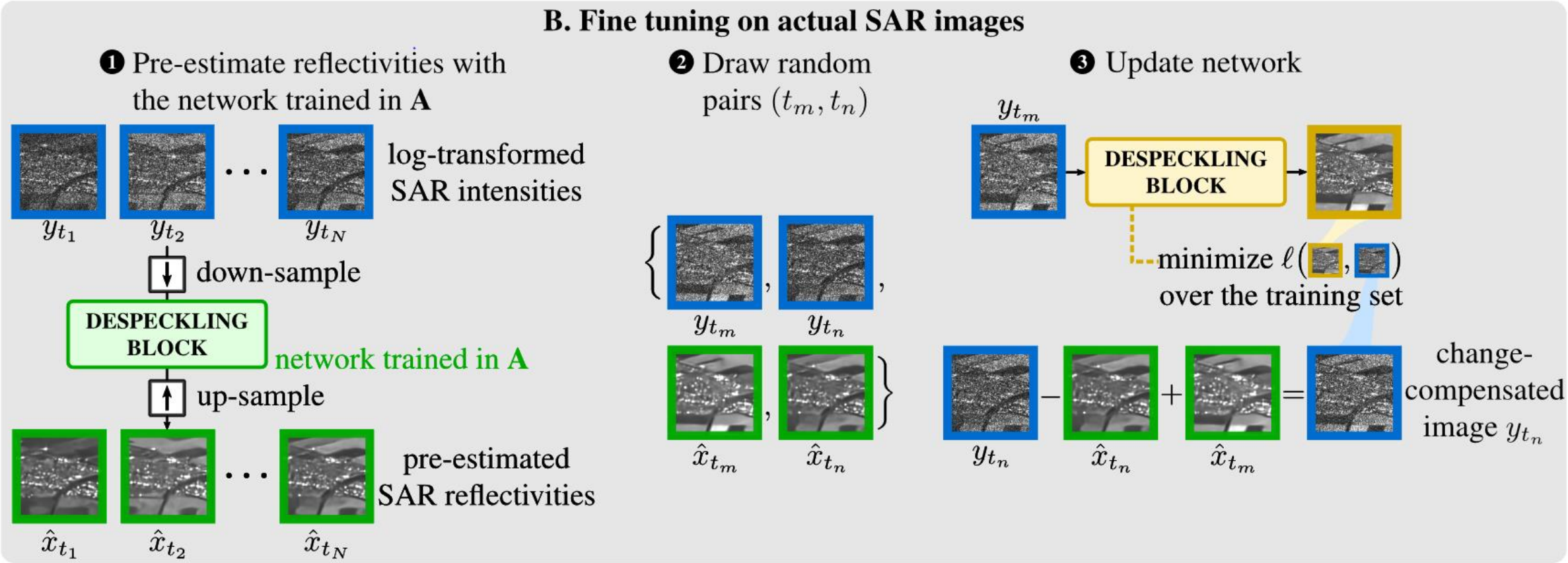




E. Dalsasso, L. Denis, and F. Tupin, "SAR2SAR: a semi-supervised despeckling algorithm for SAR images," IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing pp. 1–1, 2021.

Proposed SAR anomaly detection

Despeckling



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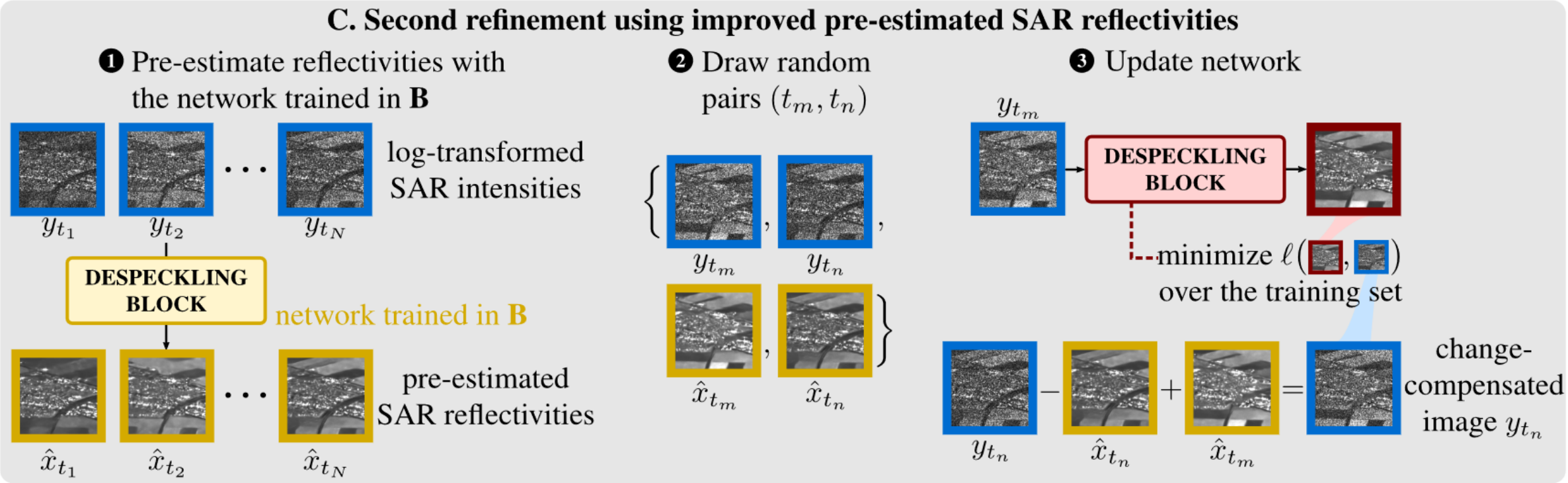
Proposed SAR anomaly detection

Despeckling



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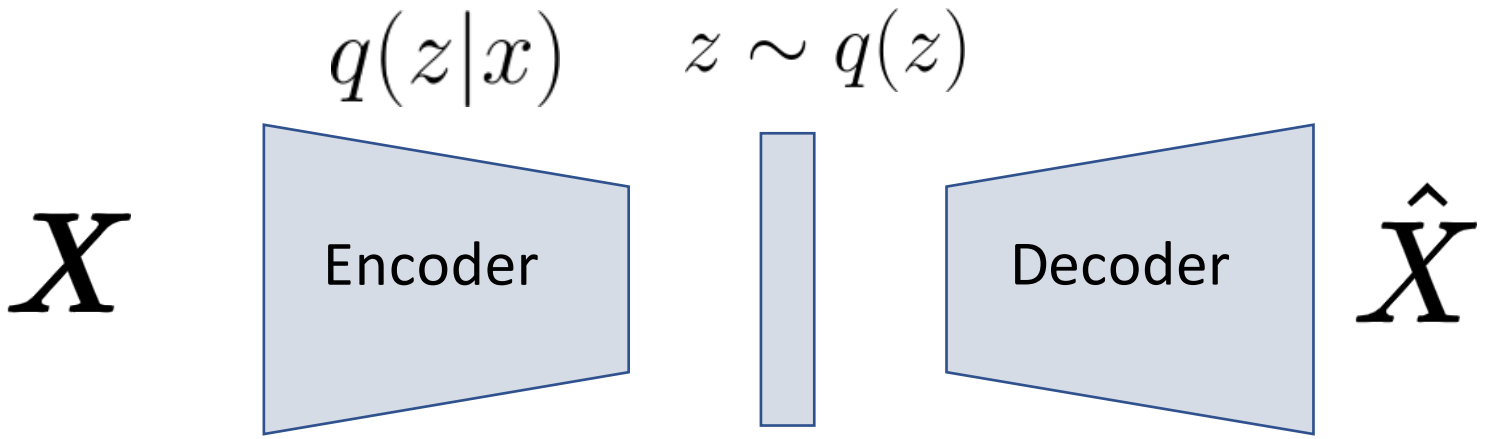
Proposed SAR anomaly detection

Autoencoder

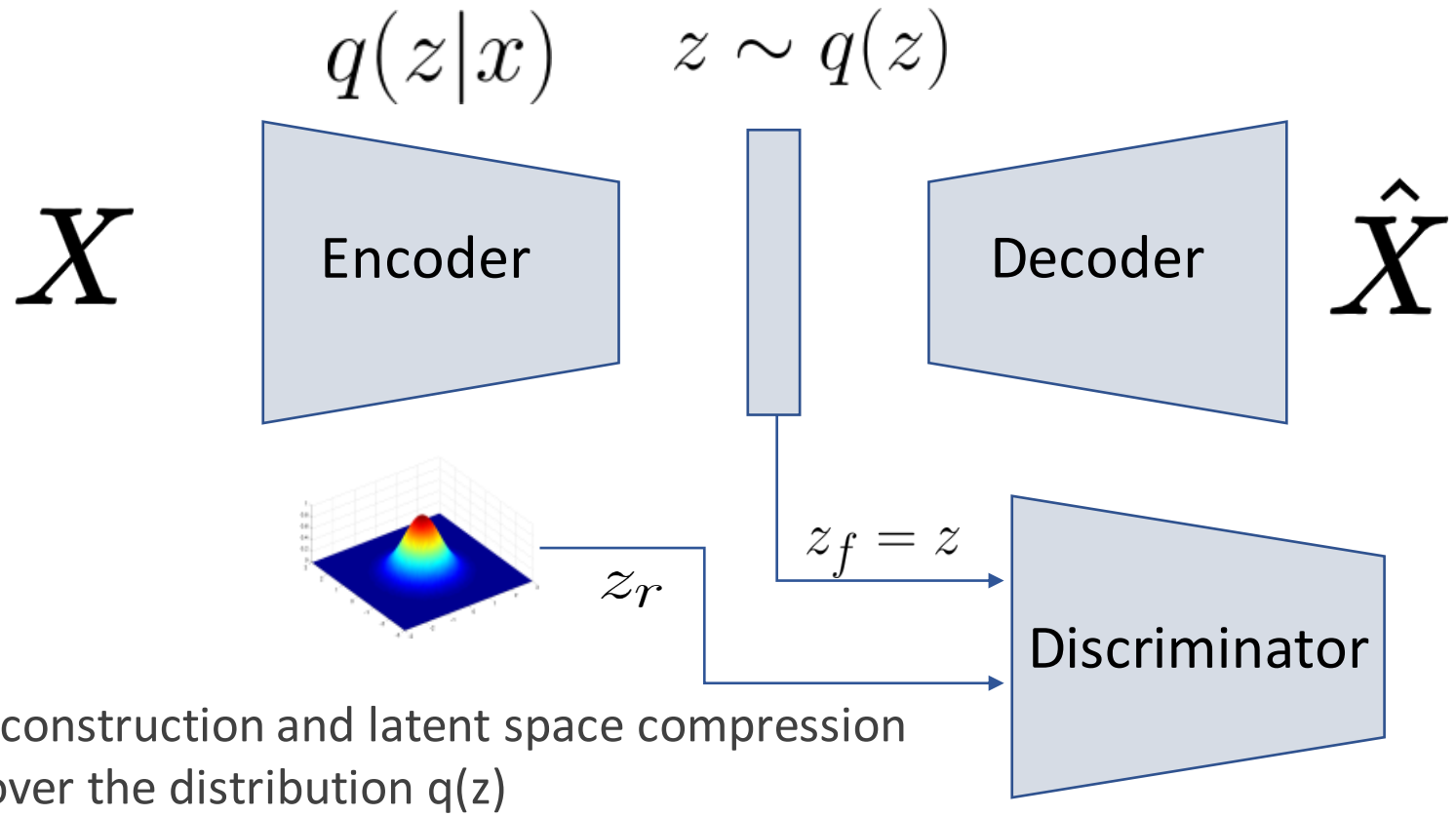


- Compress an image patch in a vector 64x64 → 128
- Only reconstructs frequently seen structures

$$L_{rec} = \frac{1}{h\,w\,c} \sum_{i,j,k} \left\| \mathbf{X}_{i,j,k} - \hat{\mathbf{X}}_{i,j,k} \right\|_1 .$$

Proposed SAR anomaly detection

Latent space

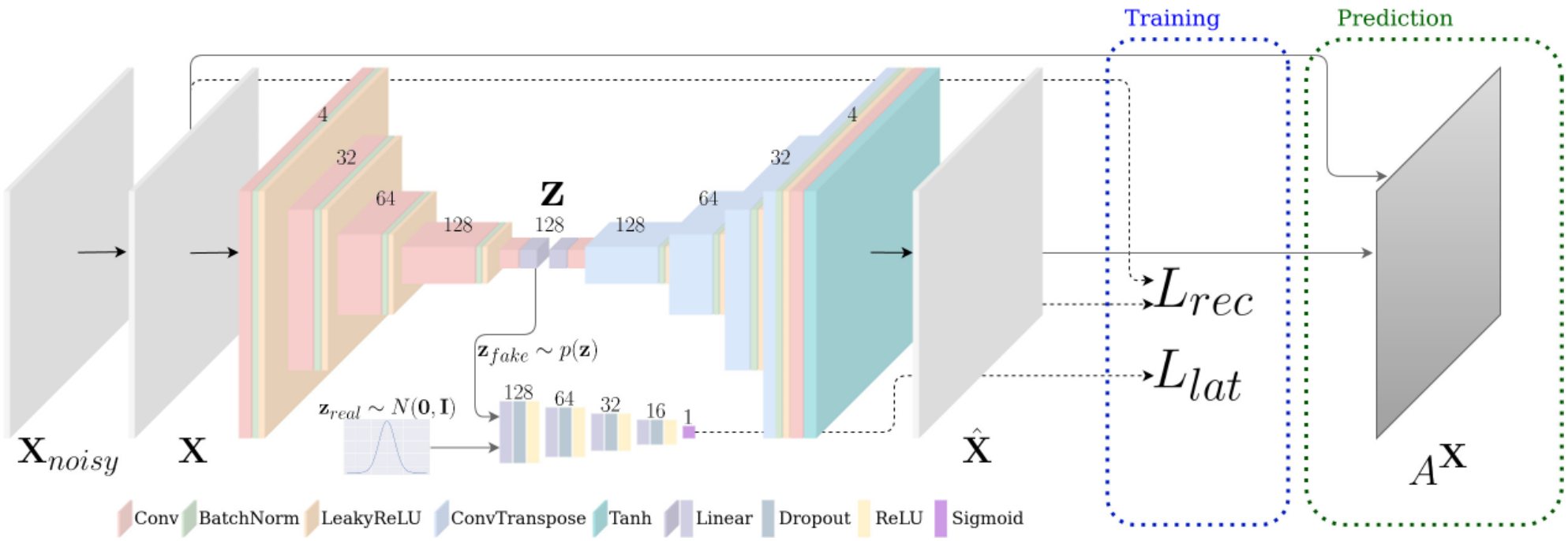


- Better reconstruction and latent space compression
- Control over the distribution q(z)

$$\min_{\mathcal{E}} \max_{\mathcal{D}_c} L_{lat} \widehat{=} \mathbb{E}_{\mathbf{z}_{real} \sim N(\mathbf{0},\mathbf{I})} \left[log(\mathcal{D}_c(z_{real})) \right] + \mathbb{E}_{\mathcal{E}(\mathbf{X}) \sim p(z)} \left[\log \left(1 - \mathcal{D}_c(\mathcal{E}(\mathbf{X})) \right) \right]$$

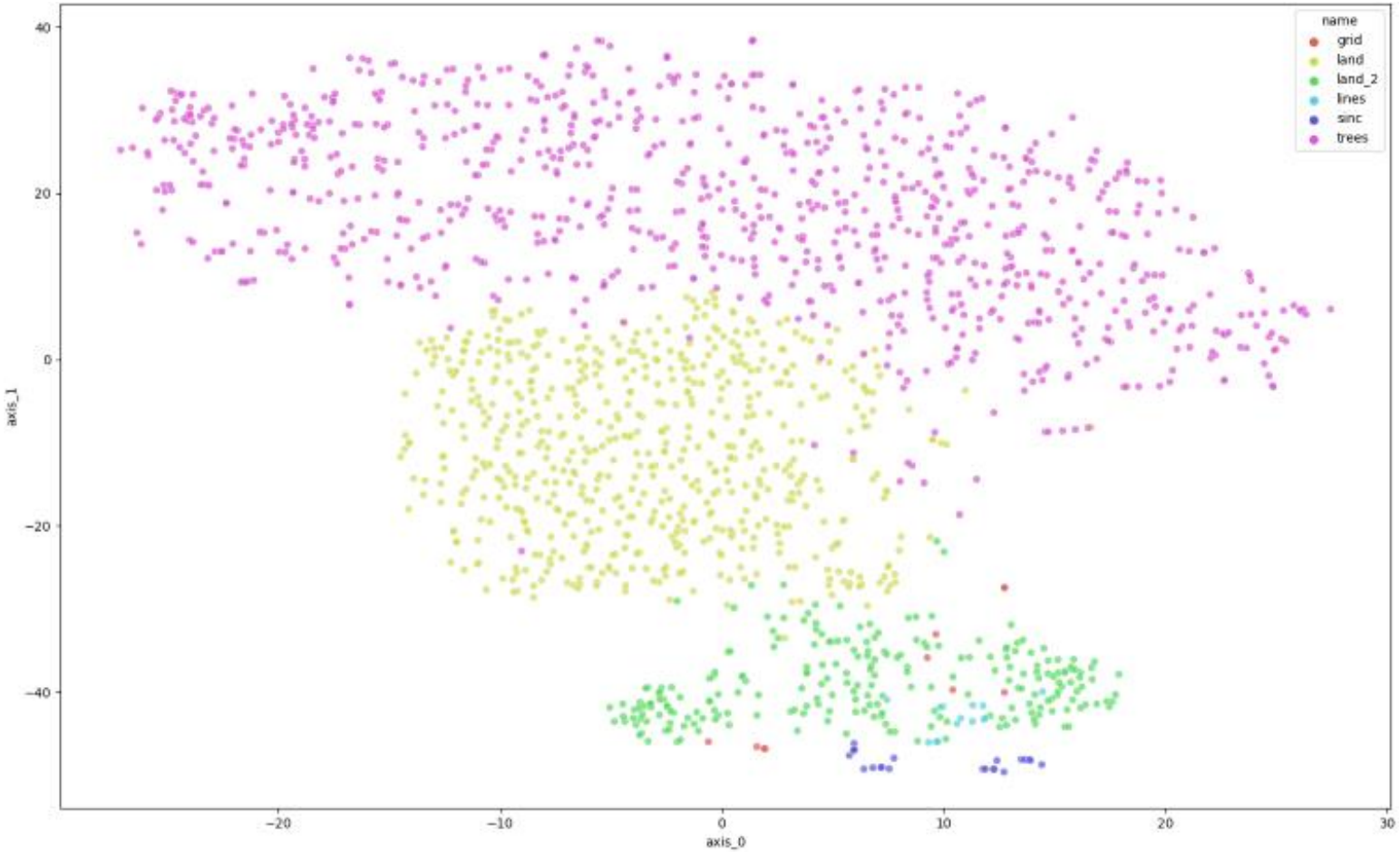
Proposed SAR anomaly detection

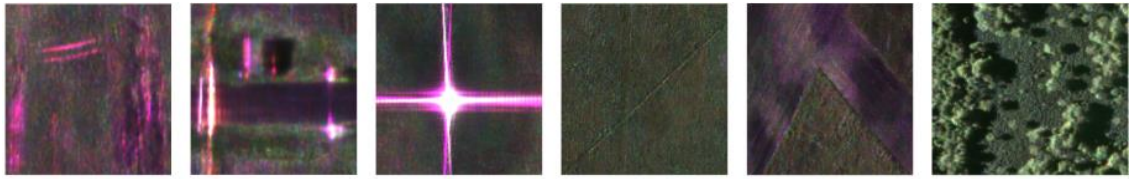
Architecture



Proposed SAR anomaly detection

Latent space analysis





lines grid sinc land land 2 trees

Proposed SAR anomaly detection

Change detection

- Covariance estimate for each pixel with a gaussian assumption

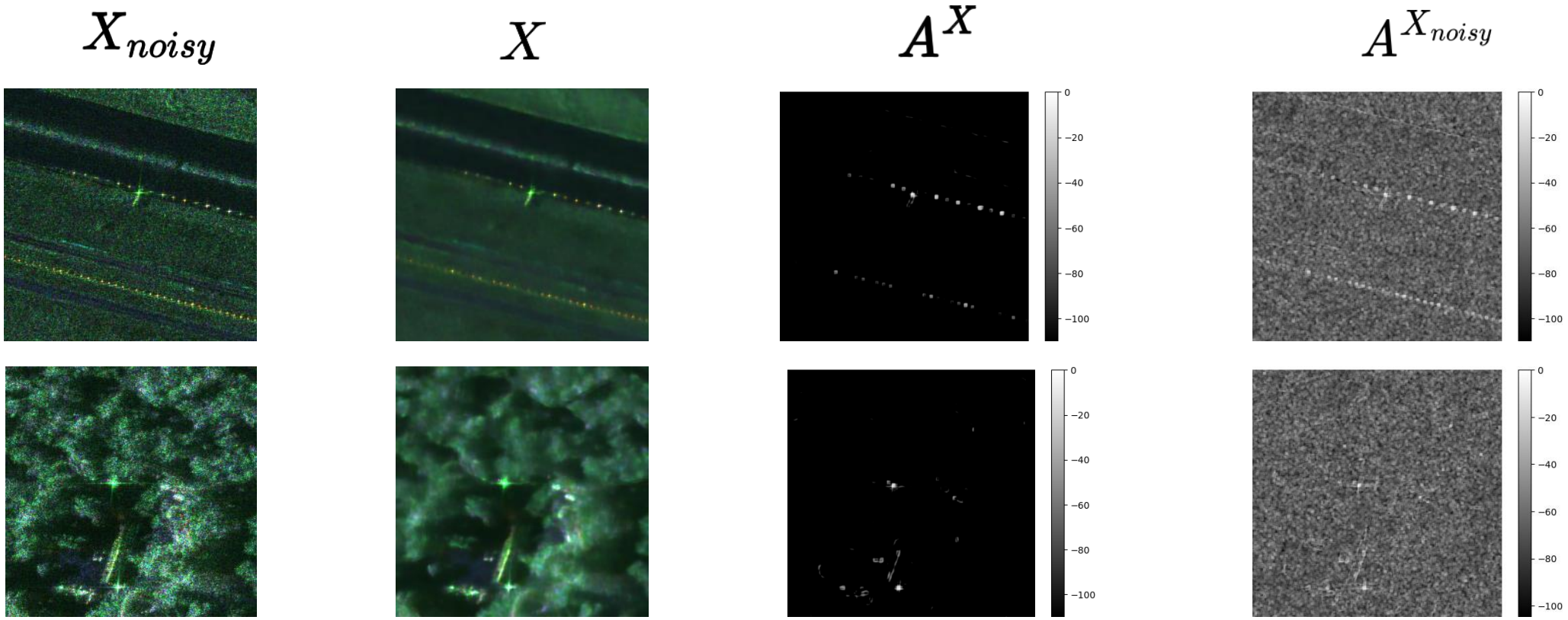
$$\hat{\boldsymbol{\Sigma}}_{k,l}^{\mathbf{X}} = \frac{1}{|\mathcal{B}_{k,l}|} \sum_{i,j \in \mathcal{B}_{k,l}} \left(\mathbf{X}_{i,j} - \hat{\boldsymbol{\mu}}_{k,l}^{\mathbf{X}}\right)\left(\mathbf{X}_{i,j} - \hat{\boldsymbol{\mu}}_{k,l}^{\mathbf{X}}\right)^T, \quad \text{with } \hat{\boldsymbol{\mu}}_{k,l}^{\mathbf{X}} = \frac{1}{|\mathcal{B}_{k,l}|} \sum_{i,j \in \mathcal{B}_{k,l}} \mathbf{X}_{i,j}\,.$$

- Euclidian distance between covariance matrices

$$A^{\mathbf{X}}(k,l) = \left\| \hat{\boldsymbol{\Sigma}}_{k,l}^{\mathbf{X}} - \hat{\boldsymbol{\Sigma}}_{k,l}^{\hat{\mathbf{X}}} \right\|_F^2$$

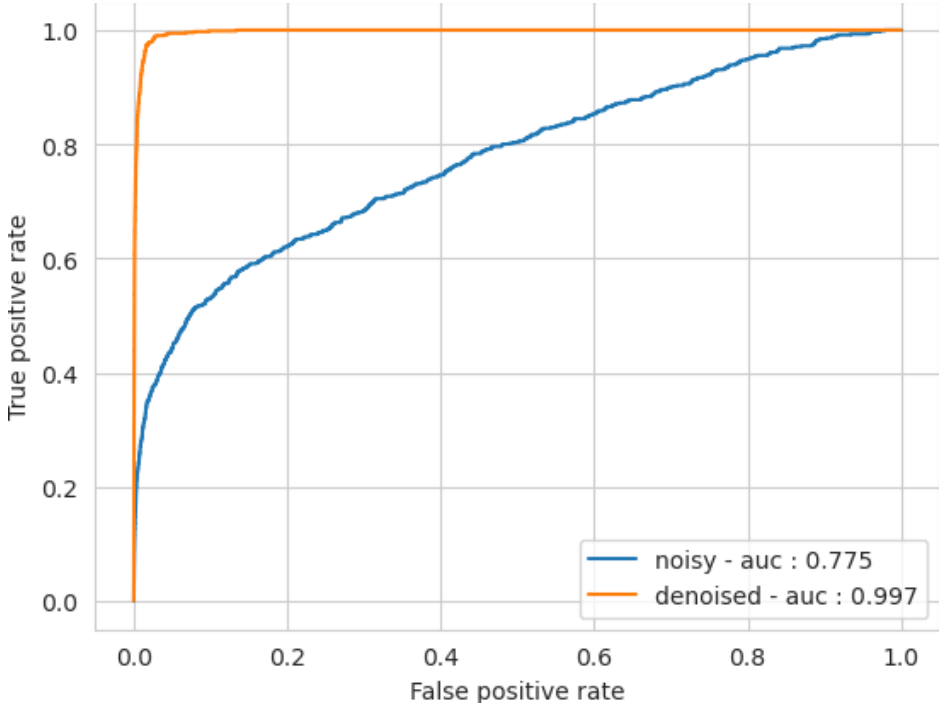
Results and comparison

Noisy vs denoised

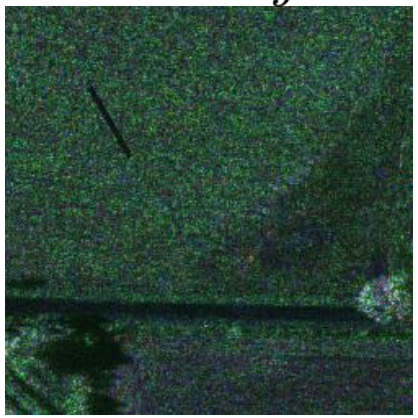


Results and comparison

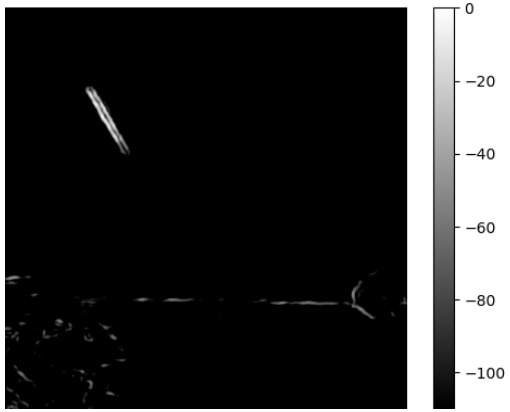
Noisy vs denoised



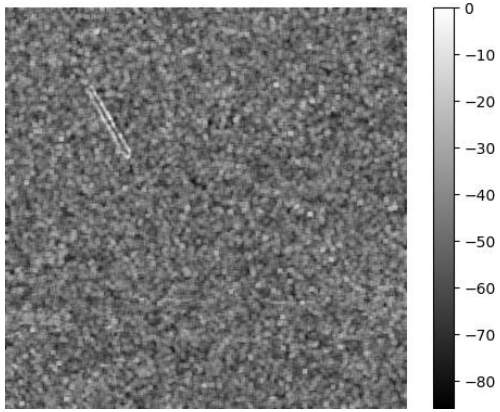
X_{noisy}



A^{X}

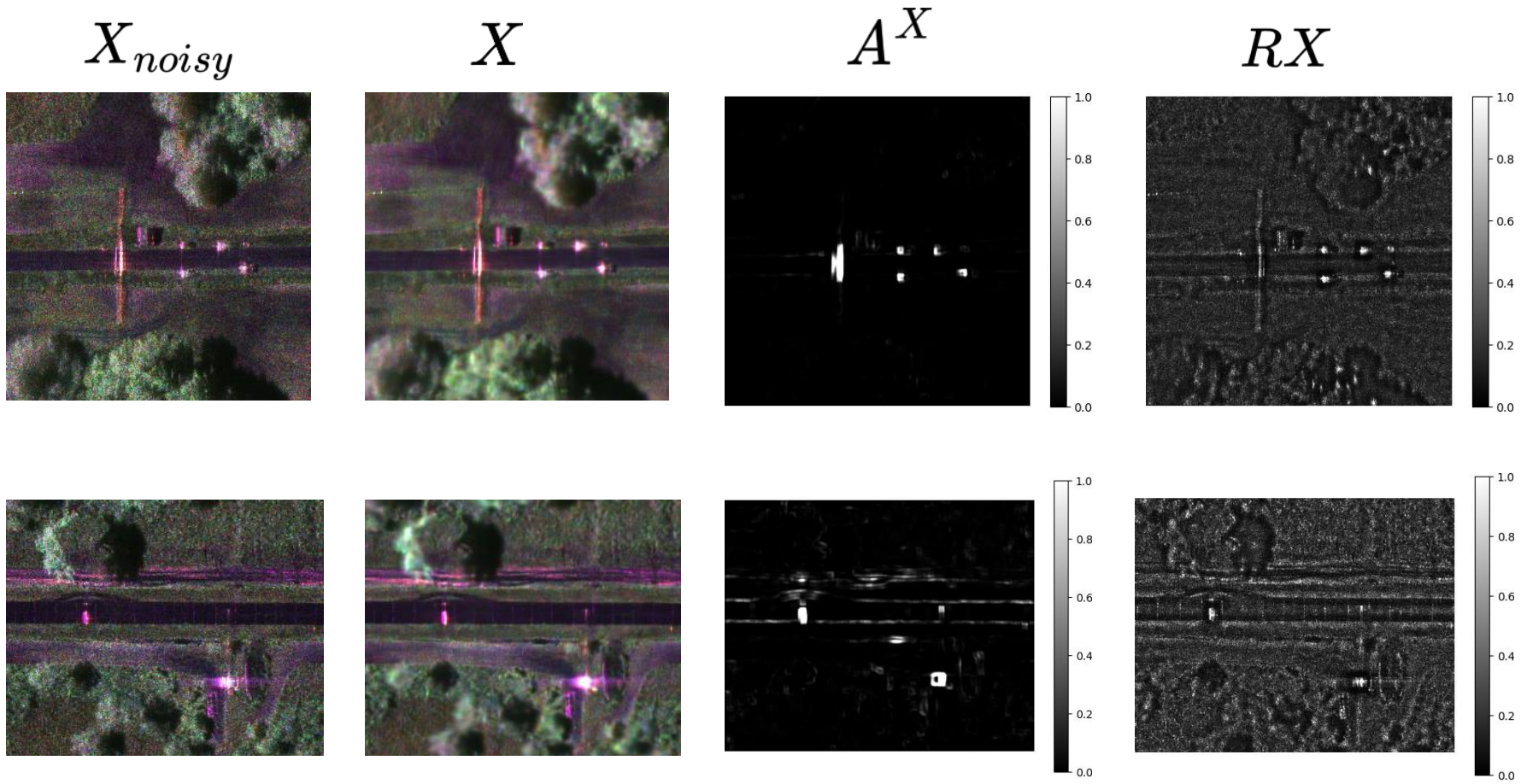


$A^{X_{noisy}}$



Results and comparison

Comparaison with RX detector



Conclusion and perspectives

- New anomaly detection method for SAR images
- Open new possibilities for deep learning detection methods

- Increase performances with a « pretext task» closer to the goal
- Assert quality with a labeled dataset