Surveillance du spectre radiofréquence

CyberExcellence

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Outline

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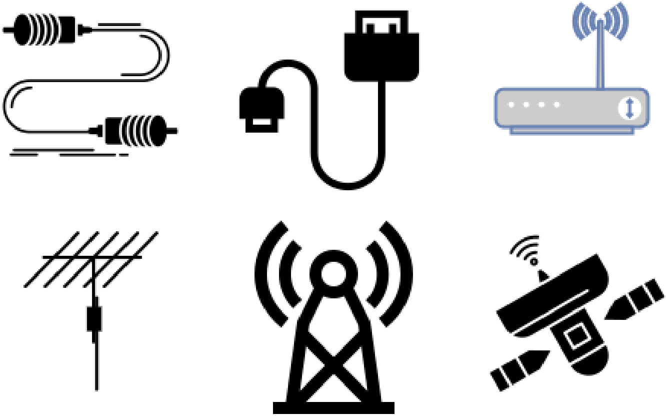
1. Domain
2. Bivariate Empirical Mode Decomposition (BEMD)
3. Methodology and Input shapes
4. Results
5. Tools
6. Challenges

Domain = physical layer



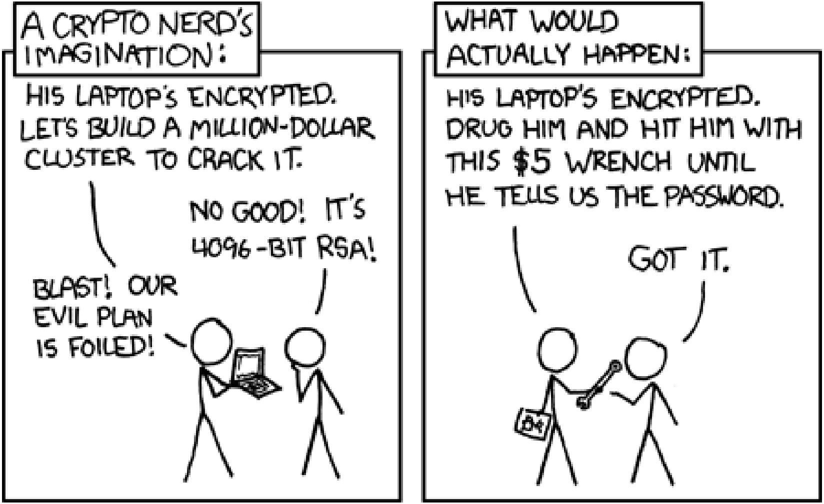


Figure: https://xkcd.com/538/

Cable cuts - recent events

Le Parisien

High-tech

Fibre optique : qui se cache derrière les coupures de câbles ?

L'enquête s'annonce complexe afin de retrouver les auteurs d'actes de sabotage contre d'importants réseaux de fibre optique.

Les saboteurs ont sciemment coupé afin de compliquer les réparations, selon les photos diffusées par l'opérateur Free qui exploite les réseaux de SFR.

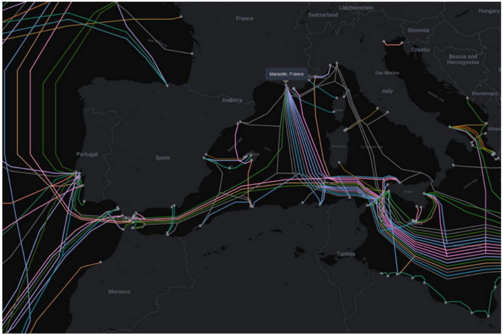
Cable cuts - recent events

Le sabotage de câbles de fibre optique en France a perturbé le web mondial

Accueil » Télécom

Télécom Par **Antoine Gautherie** le 22 octobre 2022 à 08h00 — **12 commentaires**

Un avant-goût des conséquences terribles que pourrait avoir un sabotage massif des câbles sous-marins.



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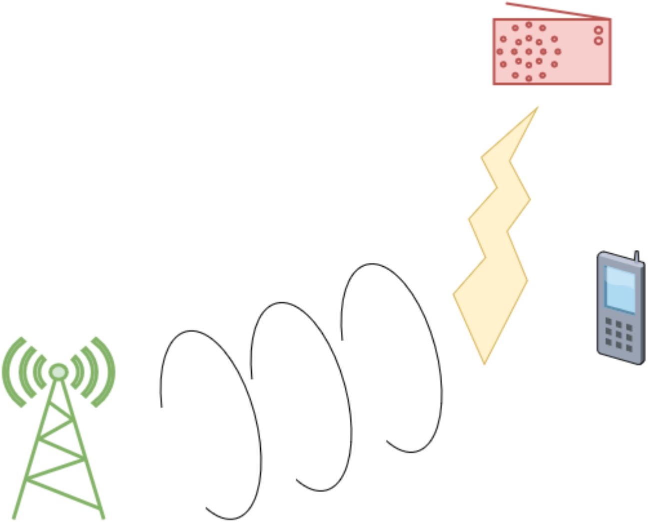
Jamming



Subject: what exactly ?

AMR $\rightarrow$ Automatic modulation recognition

- Spectrum awareness and monitoring
- CR adaptive modulation/demodulation
- Military $\rightarrow$ electronic warfare (EW) $\rightarrow$ interference avoidance
- Increase spectrum efficiency
- improve or prevent jamming attacks (drone-airport)
- other

State of the art

How to perform Modulation Recognition ?

1. Decision trees based on statistics -> classical military approach
2. Decision theoretic approach (likelihood based classifiers -> cumulative distribution functions (CDF))
3. Feature based approach (spectral features, cyclostationarity combined with Machien learning (ML): KNN SVM GA)
4. Deep learning (CNN, LSTM, Transformers, ...)

How AMR has been achieved here:
→ Fusion of signal decomposition and Convolutional Neural Networks (CNN)

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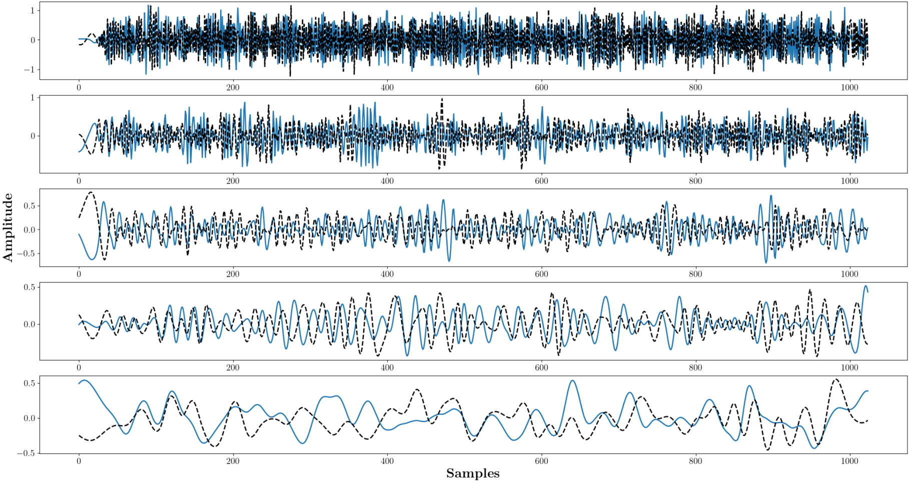
What is BEMD

EMD:

- stands for Empirical Mode Decomposition
- invented by N.Huang in 1998 [1]
- no predetermined basis function
- we obtain Intrinsic Mode Functions (IMFs) $\rightarrow$ sifting process $\rightarrow$ it is an algorithm
- applications: biomedical, natural phenomena analysis, mechanical, image, speech processing
- scarcely used in telecoms $\rightarrow$ opportunity in AMR

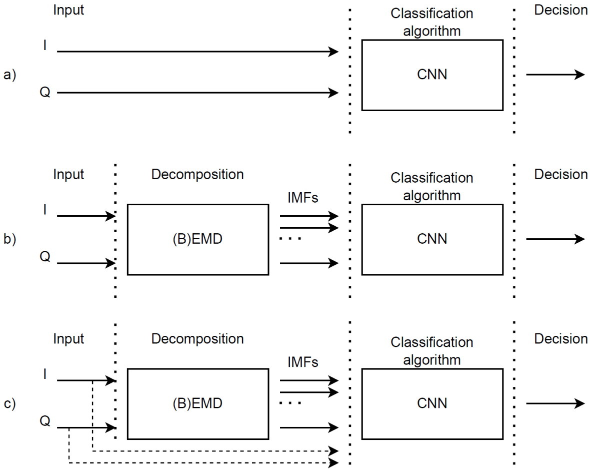
In digital telecoms: 2 variables $\rightarrow$ complex signal (IQ)
this justifies the use of Bivariate EMD (BEMD) : [2]

Example: QAM16 decomposition

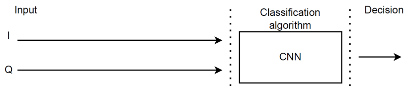


Outline

Methodology flows



Reference CNN architecture, IQ signal as input [3]



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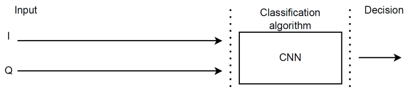
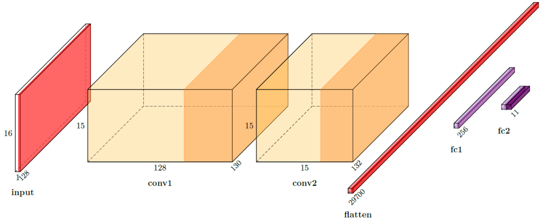
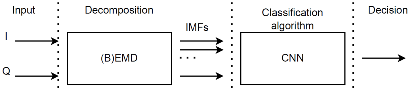




Place the IMFs one below each other



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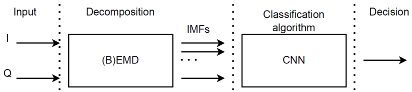

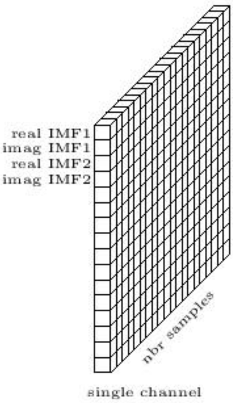

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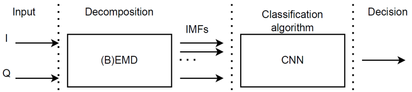
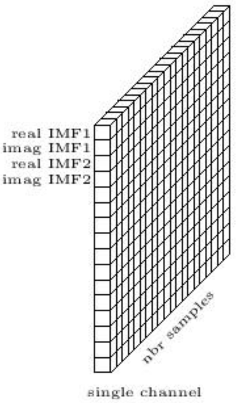
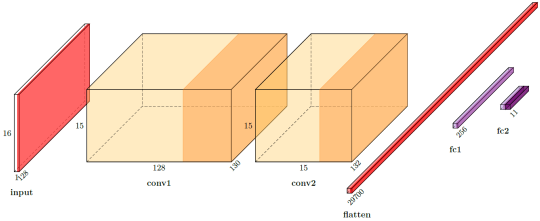
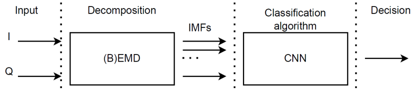






Place the IMFs into the channels (depth)



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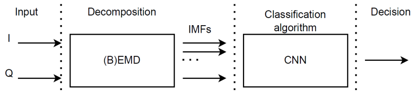

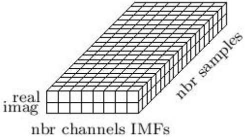

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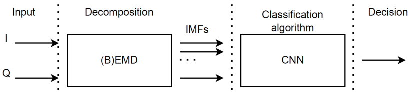
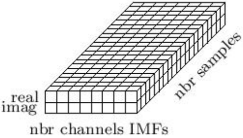
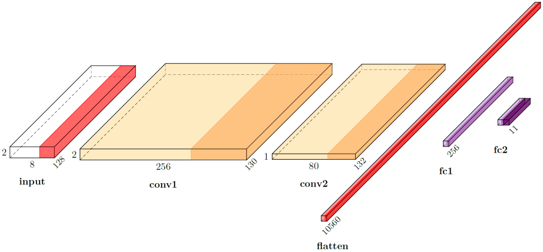


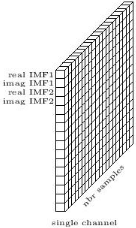




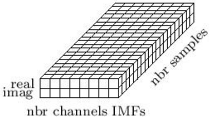
Outline

Overall accuracy improvement for each mode and w./w.o. original signal

	EMD	EMD +	BEMD	BEMD +
3D mode	0.7%	1.3%	2%	0.88%
2D mode	-12%	-4.1%	-10.3%	-3.8%

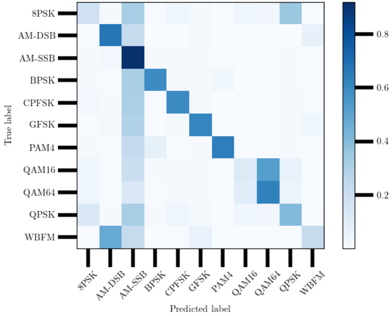


2D mode

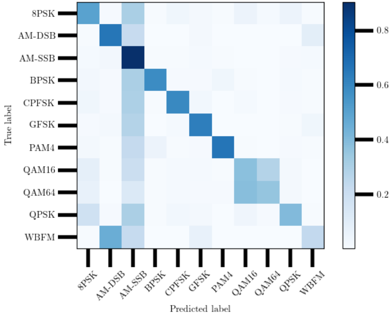


3D mode

Confusion matrices

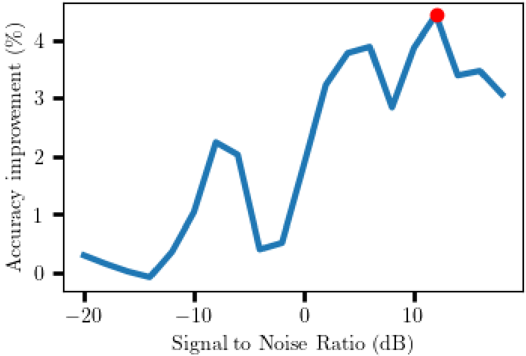


original result using IQ signal



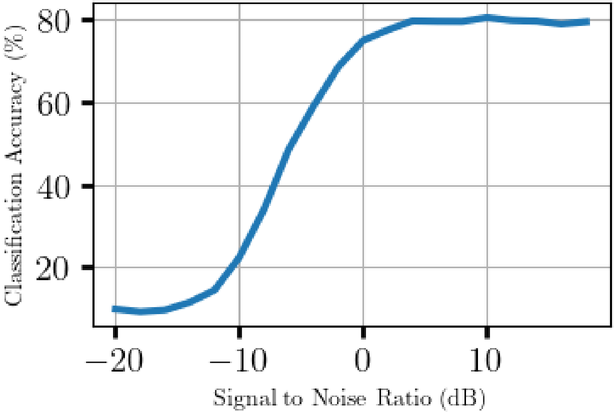
new method using IMFs

Accuracy improvement (%) for all modulations depending on SNR



- 2 % overall accuracy improvement
- up to 4.4 % improvement

Classification accuracy (%) depending on SNR



Outline

Used tools

Software:

- GRC (Gnuradio $\rightarrow$ C++,Python)
- Python (Pandas, hdf5)(Keras, tensorflow)

Hardware:

- Spectrum analyser (Keysight Fieldfox)
- Software defined radios (NI USRP 2901 = Ettus B210)

Outline

Challenges

- Find good and open databases
- Solve problems being computationally expensive
  (multi -processing, -threading; // computing etc)
  $\rightarrow$ High-performance computing (HPC - Céci)
- Explain output differences using different AI modules
  (example: Keras vs tflearn)

References [x] I

[1] N. Huang, Z. Shen, S. Long, M. Wu, H. Shih, Q. Zheng, N.-C. Yen, C.-C. Tung, and H. Liu, "The empirical mode decomposition and the hilbert spectrum for nonlinear and non-stationary time series analysis," *Proceedings of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences*, vol. 454, pp. 903–995, 03 1998.

[2] G. Rilling, P. Flandrin, P. Goncalves, and J. M. Lilly, "Bivariate empirical mode decomposition," *IEEE Signal Processing Letters*, vol. 14, no. 12, pp. 936–939, 2007.

[3] T. J. O'Shea and J. Hoydis, "An introduction to deep learning for the physical layer," 2017.

Merci

et bonne collaboration !!