The influence of Bivariate Empirical Mode Decomposition parameters on AI-based Automatic Modulation Recognition accuracy

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Outline

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Context

AMR → Automatic modulation recognition → a long history !

- Spectrum awareness and monitoring → RF scene analysis
- CR adaptive modulation/demodulation
- Military → electronic warfare (EW) → interference avoidance
- Increase spectrum efficiency (modulation cohabitation)
- improve or prevent jamming attacks
- 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 Machine learning (ML): KNN SVM GA)
4. Deep learning (CNN, LSTM, Transformers, ...)

How AMR has been achieved here:

$\rightarrow$ Fusion of signal decomposition and Convolutional Neural Networks (CNN)

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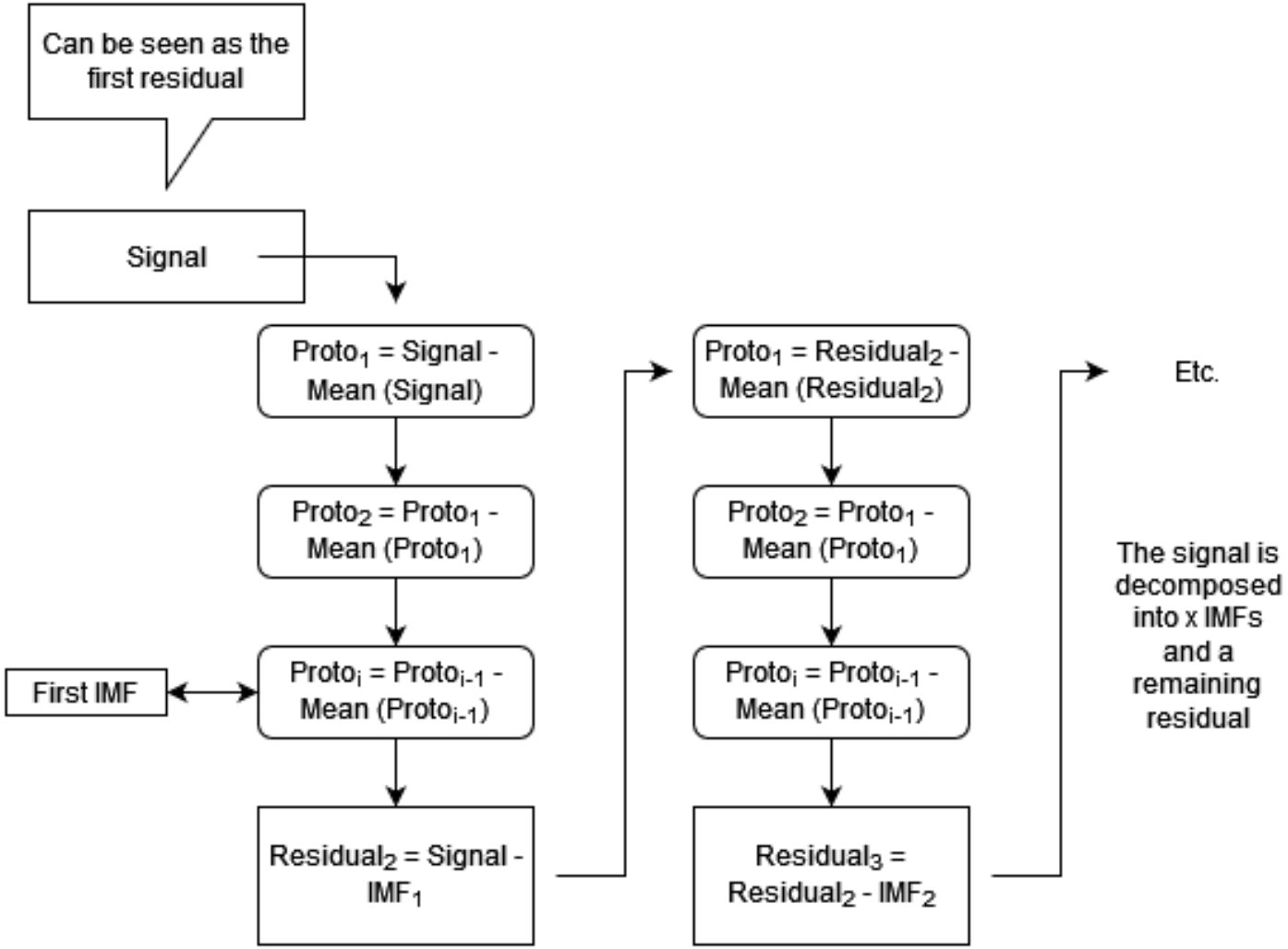
What is BEMD

EMD:

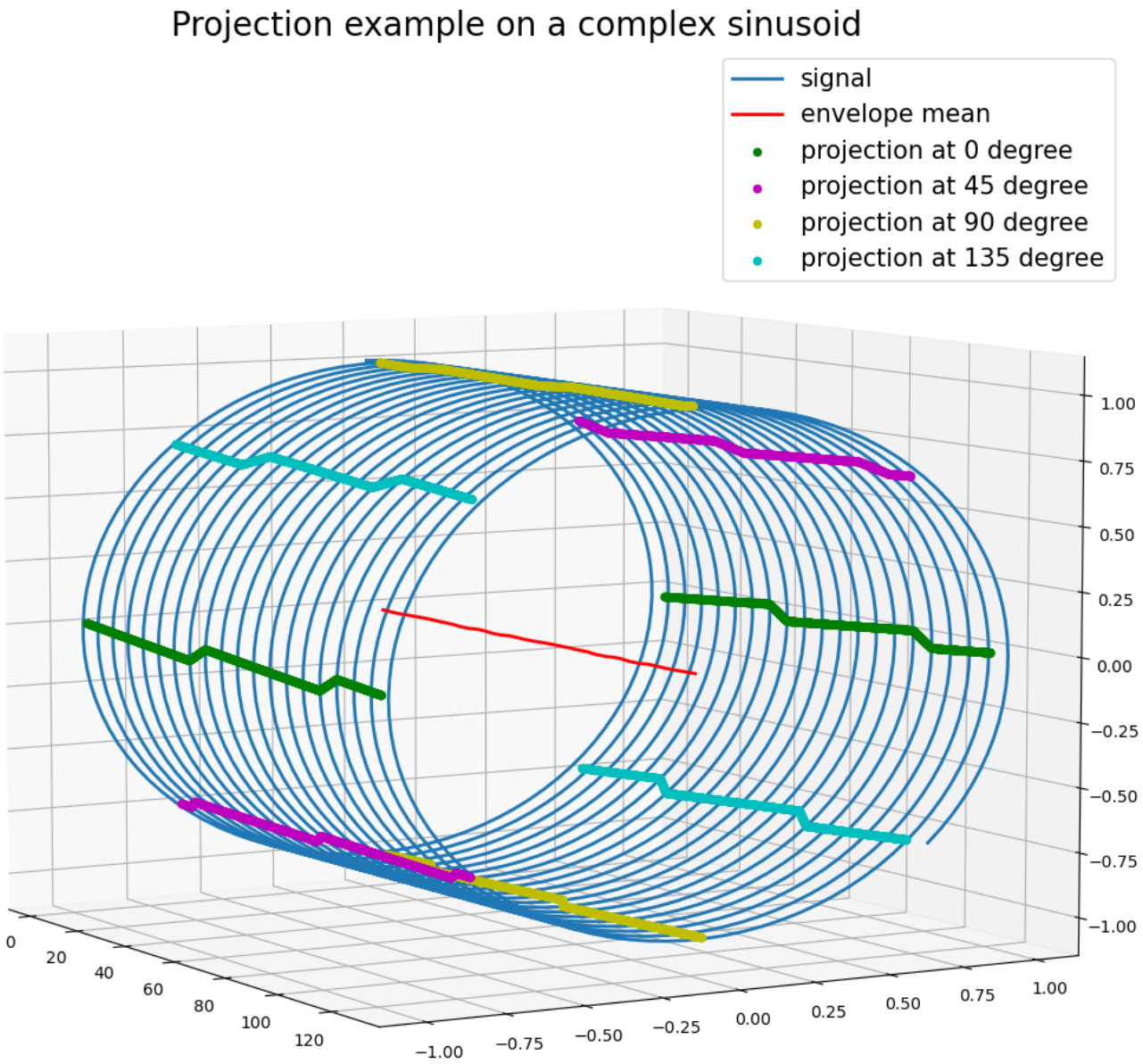
- stands for Empirical Mode Decomposition
- invented by N.Huang in 1998 [1]
- no predetermined basis function
- we obtain Intrinsic Mode Functions (IMFs) $\rightarrow$ sifting process $\rightarrow$ it is an algorithm
- applications: biomedical, natural phenomena analysis, mechanical, image, speech processing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

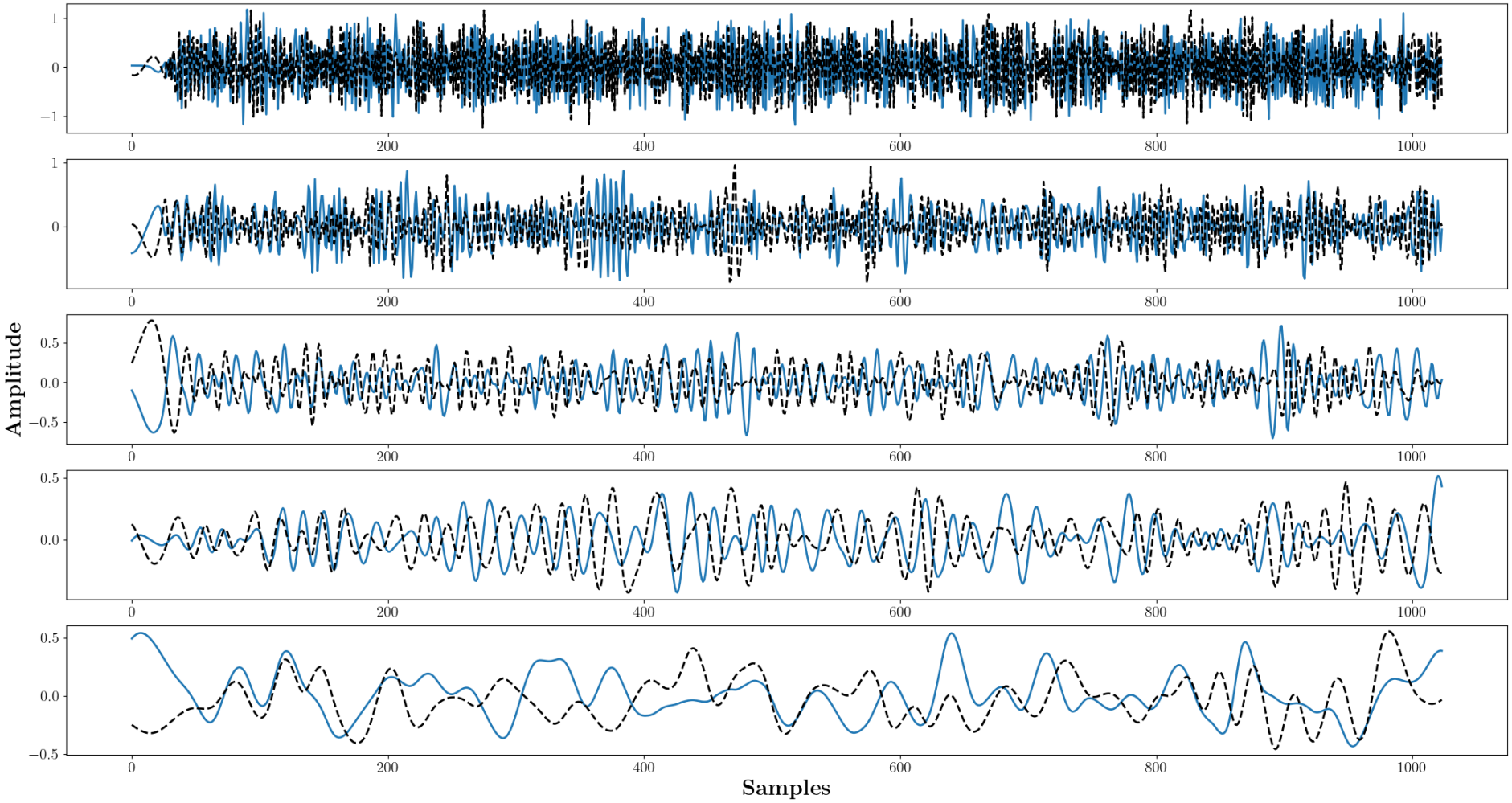
EMD decomposion flow



Projections example



Example: QAM16 decomposition



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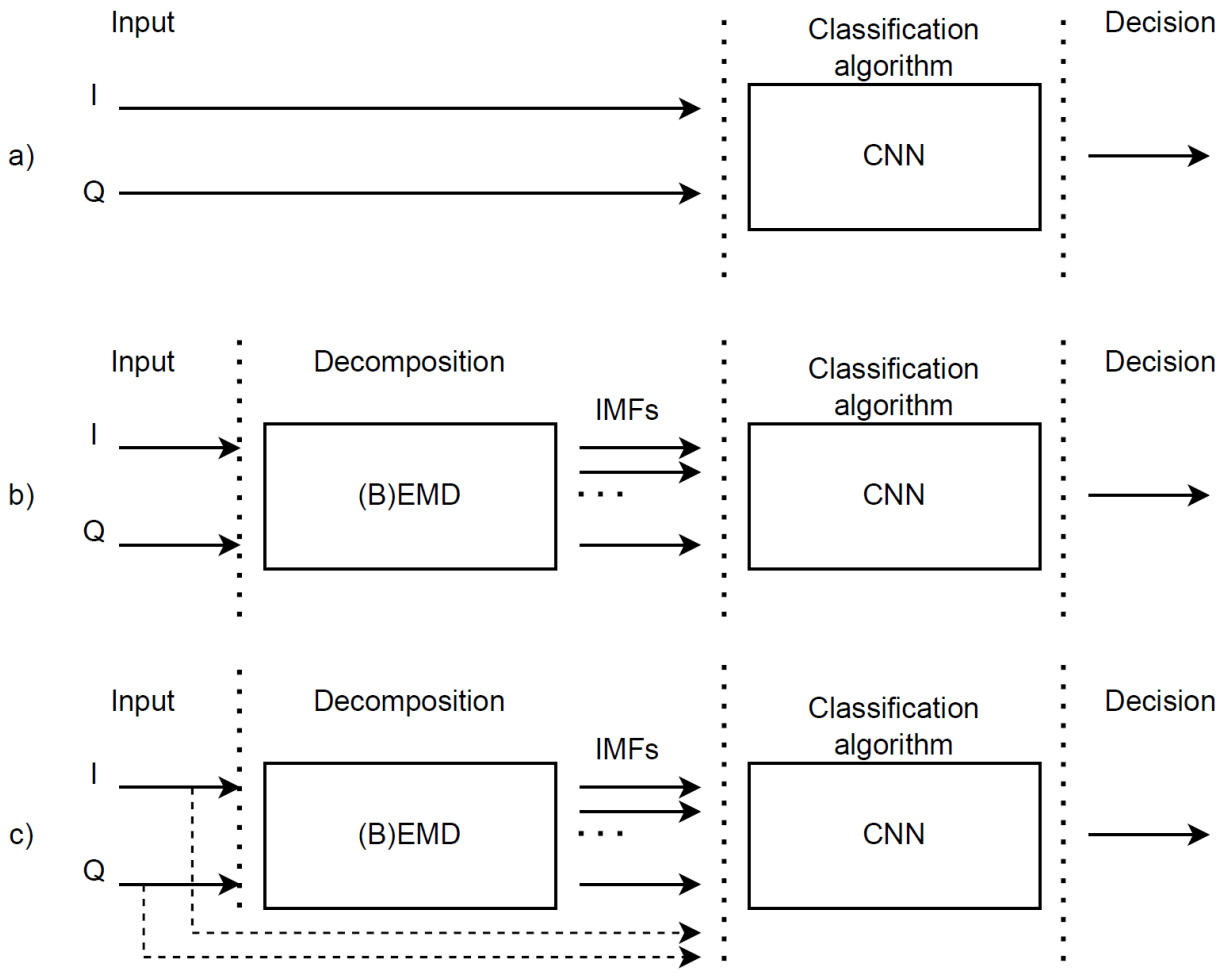
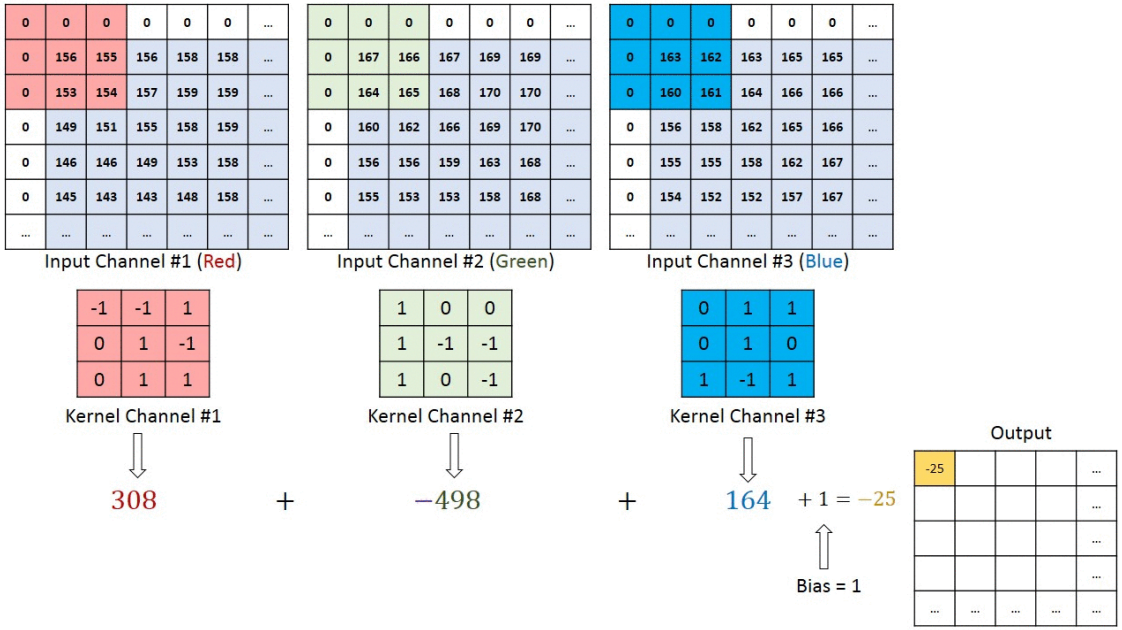
Methodology flows



CNN process

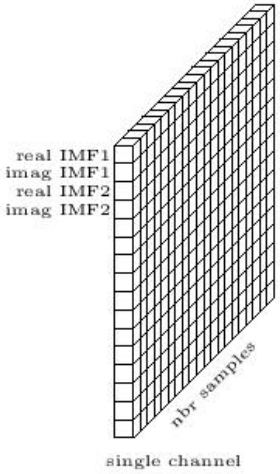


[1]

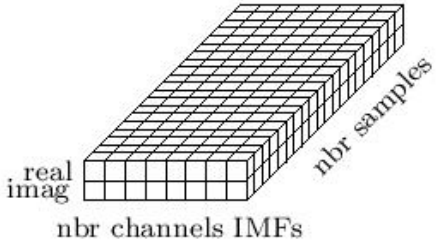
[1] https://towardsdatascience.com/a-comprehensive-guide-to-convolutional-neural-networks-the-eli5-way-3bd2b1164a53

Overall accuracy improvement for each mode and w./w.o. original signal [3]

	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 ("weighted recomposition")

Outline

Assumption and parameters ?

Assumption: increasing the number of siftings and projections would give more refined intrinsic mode functions, increasing therefore the quality of the AI architectures input, and thus the classification accuracy.

Decomposition parameters:

- number of projections
- number of siftings
- type of used interpolation

The interpolation uses most resources in the algorithm.

Cubic-spline vs Linear interpolation

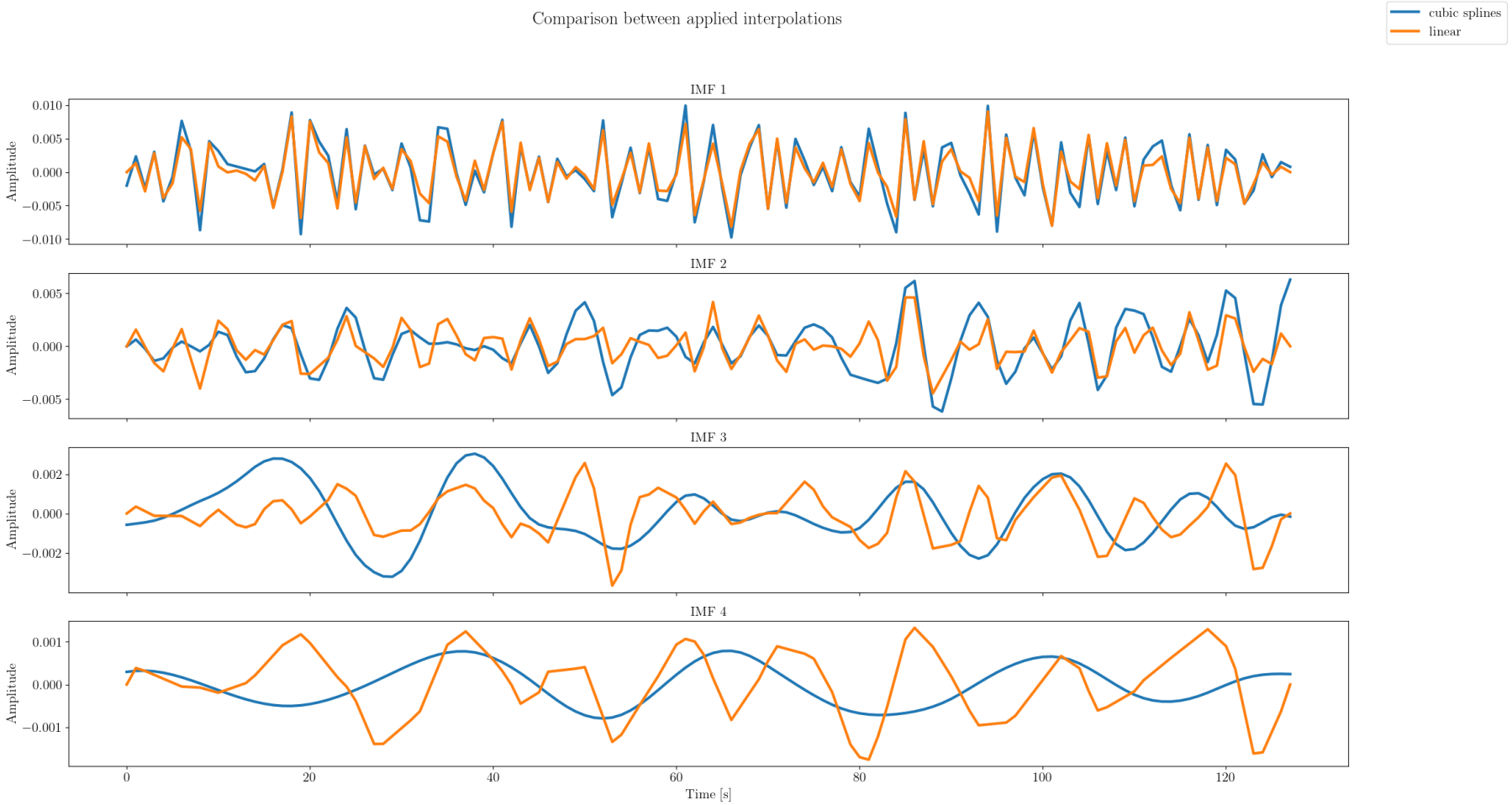


Table: Overall accuracy depending on decomposition parameters

interpolation	siftings	projections	accuracy %	approx time (min)
cubic	3	4	53,86	84
		16	54,05	310
		64	53,67	1012
	10	4	53,96	269
		16	53,94	907
		64	53,76	3917
linear	3	4	51,92	39
		16	52,93	138
		64	53,71	676
	10	4	50,73	134
		16	50,61	530
		64	50,86	2302

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Conclusion

- The parameters have very little effect on the overall accuracy of the classifier
- It seems to be an unfavorable result in the sense that we can not improve the results considerably by refining the decomposition
- But it also means that it is not necessary to use high numbers of projections and siftings that increase the decomposition times drastically in order to get good results.
- Using linear interpolation gives more IMFs

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] A. Gros, V. Moeyaert, and P. Megret, "Joint use of bivariate empirical mode decomposition and convolutional neural networks for automatic modulation recognition," in *2022 IEEE 33rd Annual International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC)*, 2022.

Thank you for your attention !!

Any question ?