Deep Learning in Wireless Communications

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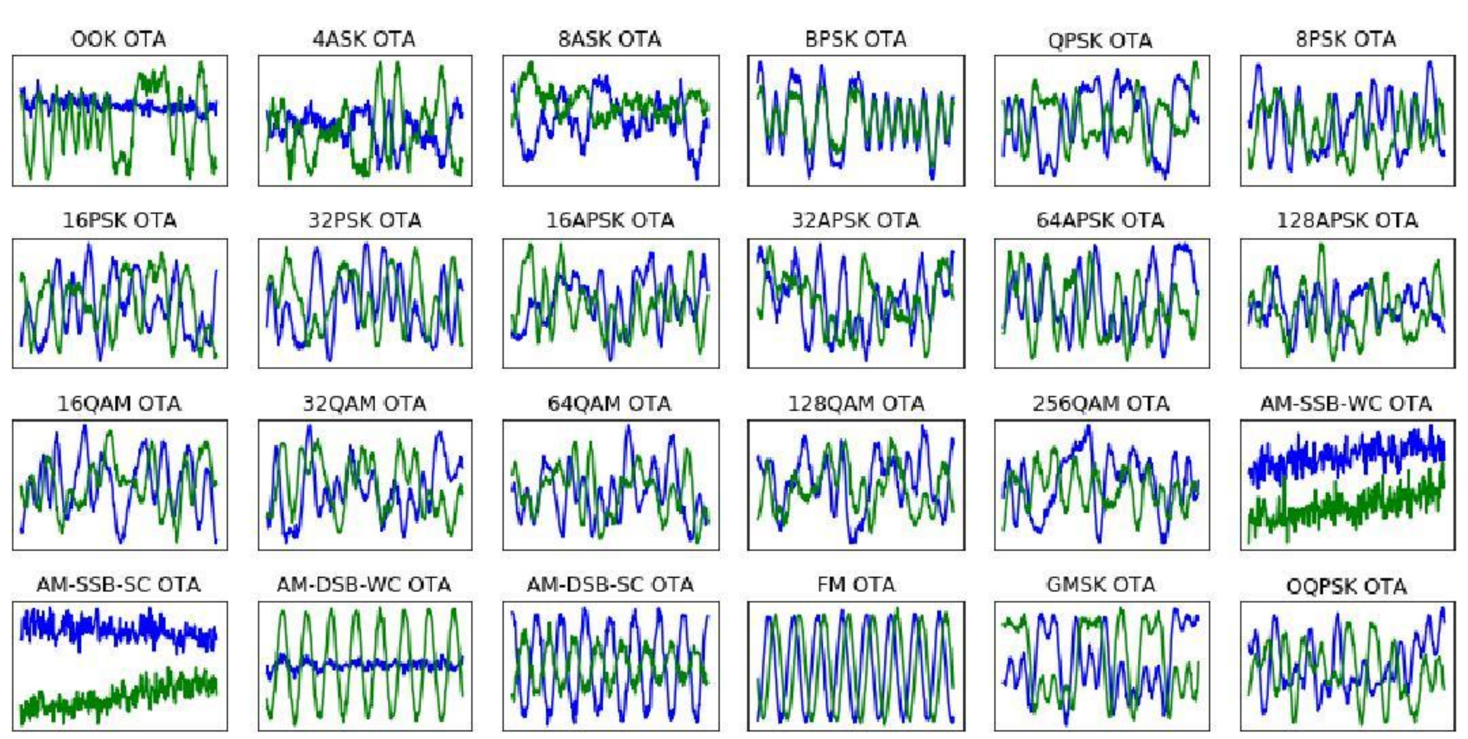
Dataset Description

We analyzed a benchmark dataset of both synthetic simulated channel effects and over-the-air recordings of 24 digital and analog modulation types [1]. Data are stored in hdf5 format as complex (IQ) floating point values. The dataset includes about 2.5 million time series, each containing 1024 time instants.



Examples of the 24 modulation types in time domain vs I/Q

Y. Bengio, G.Hinton, and Y.LeCun, the “Founding Fathers” of Deep Learning, received the ACM 2018 Turing Award, which is considered the equivalent of the Nobel Prize for Computer Scientists.

WIRELESS COMMUNICATIONS

is a method of transmitting information from one point to another, without wires.

DEEP LEARNING...

...tries to mimic the functionality of the human brain, re-organizing the information through several layers (“depth”) of filtering so that a computer can provide the essential answers (“learning”) to the task of interest. Due to the complexity of this simulated brain structure, this procedure requires the computational power now available. Deep Learning has revolutionized several research fields in the past ten years and is producing an explosion of state-of-the-art results [3]. It is and will continue to play a crucial role also in Wireless Communications.

GOAL: Spectrum Occupancy Prediction

The wireless ecosystem is getting saturated and frequency band allocation needs to become dynamic in order to optimize spectrum occupancy and satisfy current needs. We propose to use tools of data science and deep learning to attack the **Spectrum Occupancy Prediction** problem [4]. Our first assessment concerned the prediction of the modulation type, given the time series observed. The problem is not trivial, especially in the presence of multiple co-existing systems.

Shallow & Deep Time Series Analysis

A time series $\{Y_t\}_{t\in T}$, follows an **ARMA (p,q)** process, if

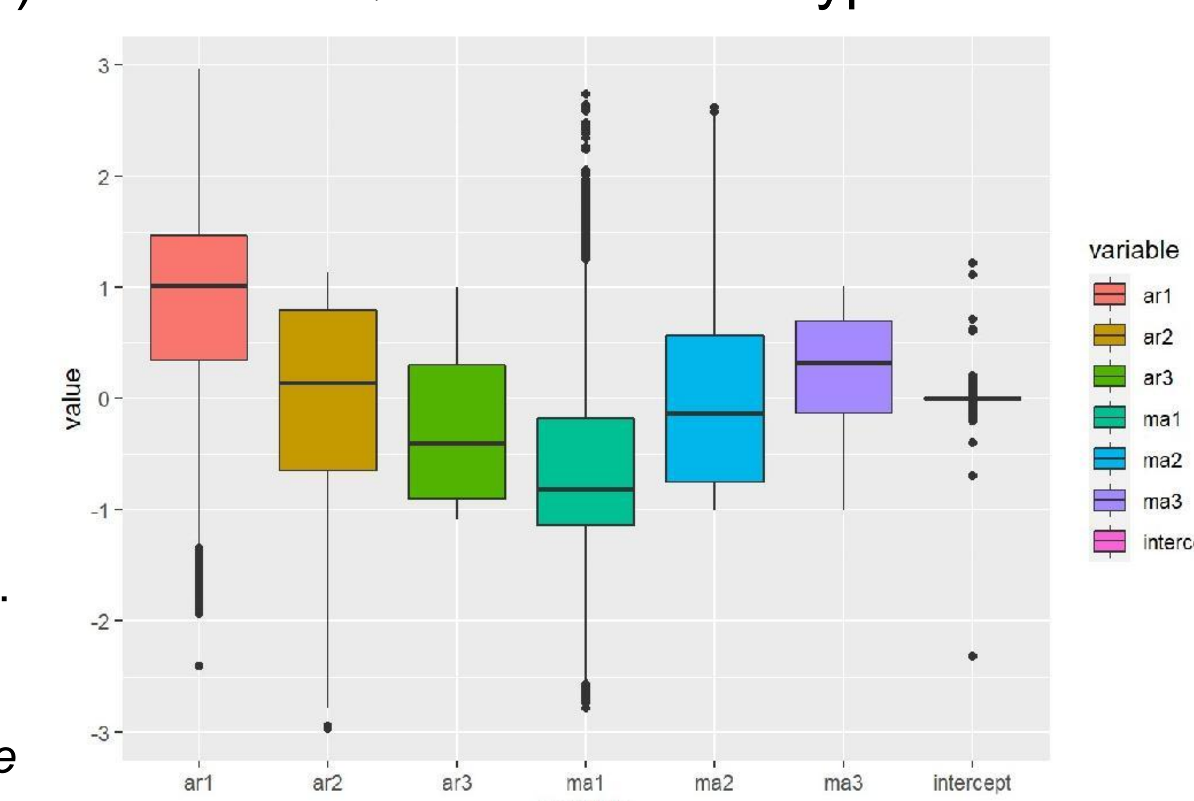
$$Y_t = \varphi_1 Y_{t-1}+\varphi_2 Y_{t-2}+\ldots+\varphi_p Y_{t-p}+e_t-\theta_1 e_{t-1}-\ldots-\theta_q e_{t-q},$$

with $\{e_t\}_{t\in T}$ is white noise with *Corr* $(e_t, Y_s) = 0$ for every $s<t$, and parameters $\theta_1,\ldots,\theta_q;\ \varphi_1,\ldots,\varphi_p \in \mathbb{R}$

Results

Classical Time Series

We modeled the IQ time series using **ARMA(3,3)**, **ARMA(0,6)** and **ARMA(6,0)**. These models do not reach the prediction accuracy of deep models, but provide useful interpretations. Below is a box plot, depicting the significance of some of the ARMA(3,3) coefficients (ar1, ar2, ar3, ma1, ma2, ma3) of the 256 QAM modulation type.



Fully Connected Neural Networks

The Deep Learning algorithm we tried is a FCN [1,2,4] with 4 layers and about 600k parameters. We currently have 5 times higher than chance prediction accuracy on the 24 classes complete classification problem.

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References

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