RF Signal Classification

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Goal and Overview

Develop and implement a technology which examines and classifies radio frequencies through the use of patterns and characteristics of the signal passing through the hardware device. To achieve this we incorporated the following steps:

- Create/utilize RF algorithm for sorting and identifying patterns among RF signal
- Make the algorithm flexible and able to incorporate varying signal types
- Standardize RF signal data into a clear dataset groups organized by technology type

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Dependencies

Software:

DL: Theano, TensorFlow, Keras, OpenAI Gym, KeRLym
Environment: Docker, Github, Conda
ML: Scikit-learn, OpenCV, PyOpenPNL, Pandas
SDR: GNU Radio + several useful out-of-tree gr-modules

Hardware:

PowerPC: Minsky
X86: Ubuntu, MacOS, Windows
SDR: HackRF

Research and Implementations

Frequency technologies

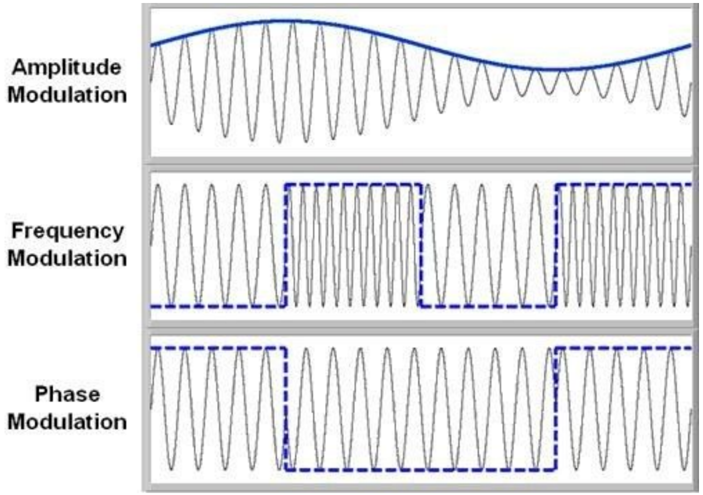
- Wifi GSM GPS LTE Zwave

Frequency modulation

- AMSSB PAM QAM PSK CPFSK

RadioML research

- Signal processing design uses AI to learn optimized models directly from data rather



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The Need for RF Classification

The Radio Frequency Spectrum ranges from around 3kHz to 300GHz and is widely utilized to carry communication signals. Few of these communication signals vary including

1) Radio broadcast signals such as AM & FM
2) Cell phone signals such as LTE, GSM, GPRS, EDGE etc.
3) GPS Signals positioning.
4) Computer Network Signals commonly as WIFI & Bluetooth.

These protocols have different modulations and frequencies associated with them. As, It would be quite a task to identify these signals manually consisting of too many human errors we can make use of Deep Learning & Machine Learning Techniques to classify these signals.

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Types of Protocols & Modulations

We researched the basic protocols and the types of modulations associated with each protocol.

By getting to know this we had a better understanding and incorporated these protocols and modulation types in our algorithm for detailed classification

PROTOCOL	MODULATION
Wifi	QPSK,(Quadrature phase shift keying)
Bluetooth	GFSK, Gaussian frequency-shift keying
GSM	GMSK. Gaussian Minimum Shift Keying
LTE	OFDM (Orthogonal frequency-division multiplexing)
Zigbee	DSSS (Direct Sequence Spread Spectrum) / OQPSK
Zwave	GFSK, Gaussian frequency-shift keying
GPS	BPSK (Bi-Phase Shift Keying)
AM	Amplitude Modulation

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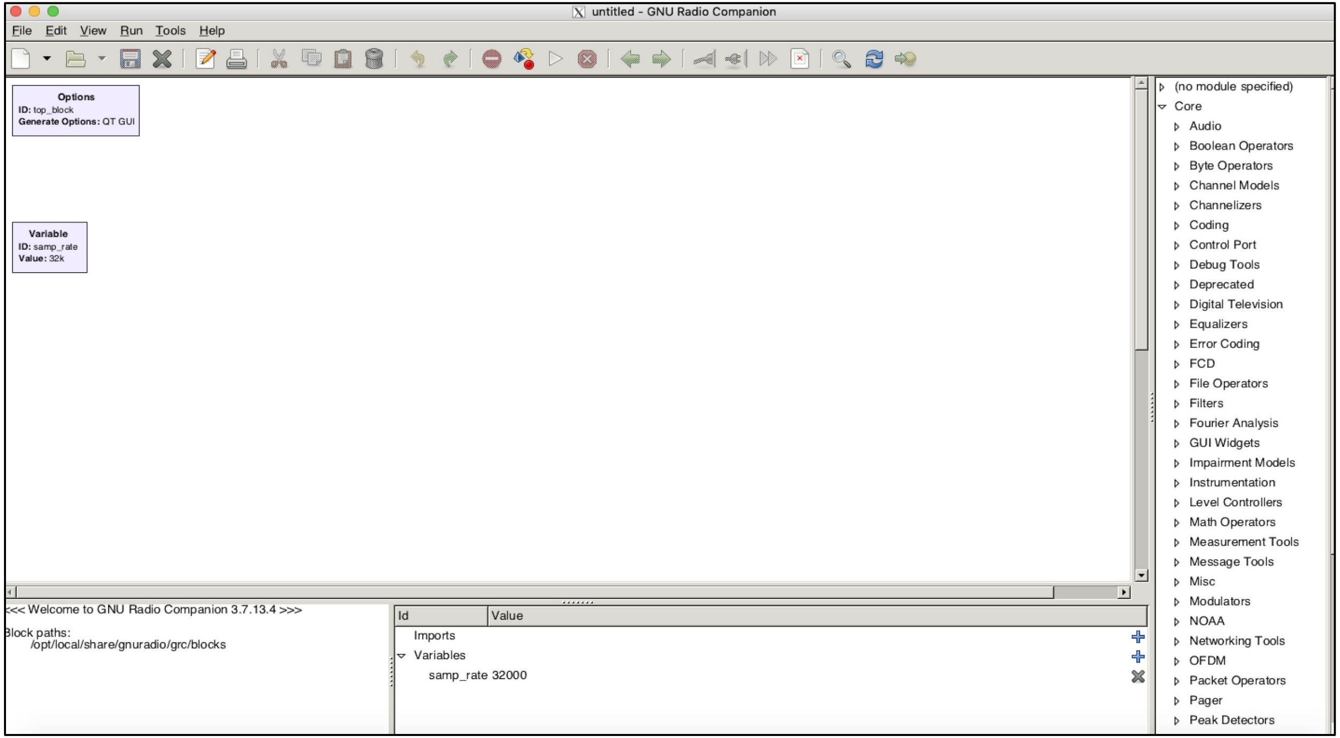
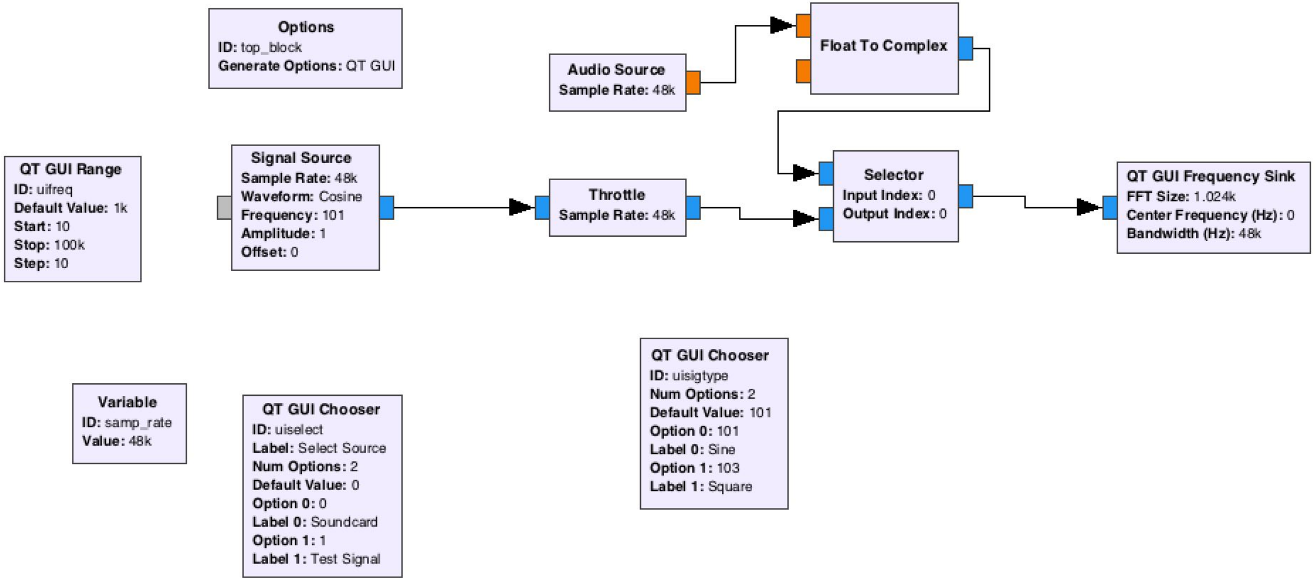
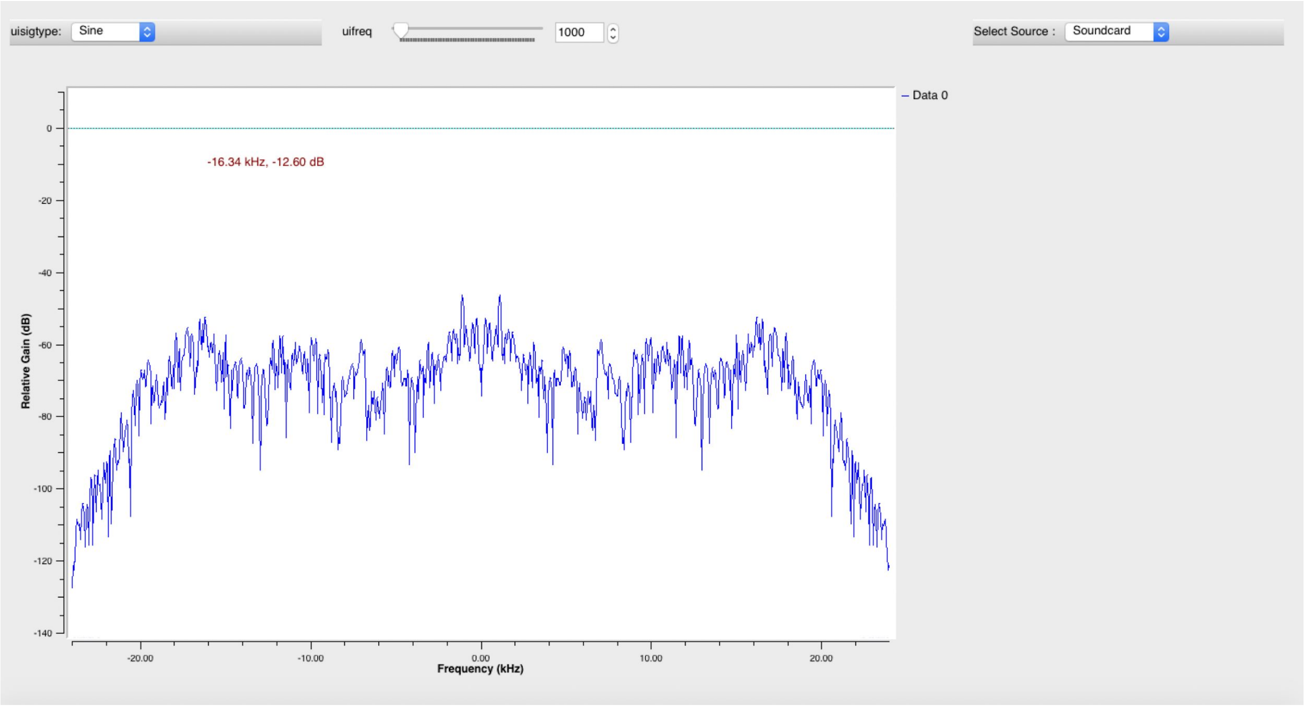
GNU Radio Interface



Audio/Sound Card Generated RF Signal



Waveform Generated for the RF Signal



Data Processing/Generation

Deepsig Dataset:- Deepsig is currently working on developing methodologies for optimization of RF signals using Machine Learning.

Dataset Used:- RadioML 2018.01.OSC The Dataset used here is generated with GNU Radio, consisting of 24 modulations at varying signal to noise ratios.

Data Format

Data file: RML2016.10a_dict.pkl

The file was in pickled format and the data that was saved contained one large Python dictionary array. The data format looks like below

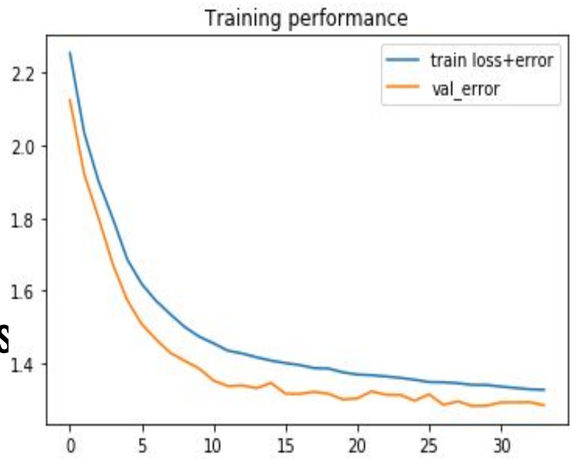
{('mod type', SNR): NumPy array(nvecs_per_key, 2, vec_length)}

8 digital and 3 analog modulations. These consist of BPSK,QPSK,8PSK,16QAM,64QAM,BFSK,CPFSK,and PAM4 for digital modulations, and WB-FM, AM-SSB, and AM-DSB for analog modulations. Noise ratios varied from -20 to 18 dB

Model Training

Model: VT-CNN2 Neural Net model using Keras

Overview of model creation algorithm:
-Reshape [N,2,128] to [N,1,2,128] on input
-Pass through 2 2DConv/ReLu (rectified linear) layers -Pass through 2 Dense layers (ReLu and Softmax)
-Perform categorical cross entropy optimization

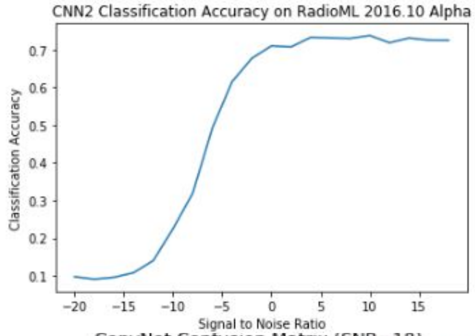


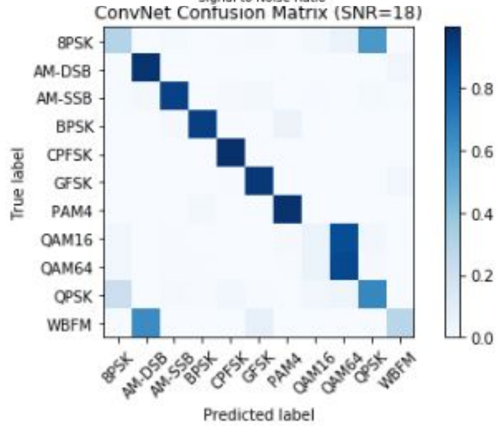
Modifications made in the Template to make it compatible with Python 3.5

- Imported Pickle library instead of cPickle. Updated 'cPickle.load' command to 'pickle.load' and included 'encoding' parameter in the call.
- 'map' function in python 2.7 directly returns list of values, but in python 3.5 it returns a map object. This was creating errors while running the code. This was fixed by explicitly using the 'list' function in multiple places to list values of map object.

Model Summary

Accuracy: 73%
Signal to Noise Ratio: -20dB to 18dB
No of samples Trained: 110000
Samples validated: 110000
Training time: 22 Hrs
Data Size: .611GB





Future Implementation

Finalizing a program which incorporates the trained model and utilizes it to identify specific patterns related to protocols.

Implement a live recording format of feeding HackRF collected signal into model implementing program.

References

https://arxiv.org/pdf/1712.04578.pdf White Paper covering "Over the Air Deep Learning RF"
https://github.com/radioML/dockerRML Data collection and model creation resource
https://github.com/sofwerx/deepsig_dataset Ian modified and collected the RadoiML dataset
https://github.com/petelS/RFClassification our repository of all files and code.

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