Automatic Modulation Classification using TCN

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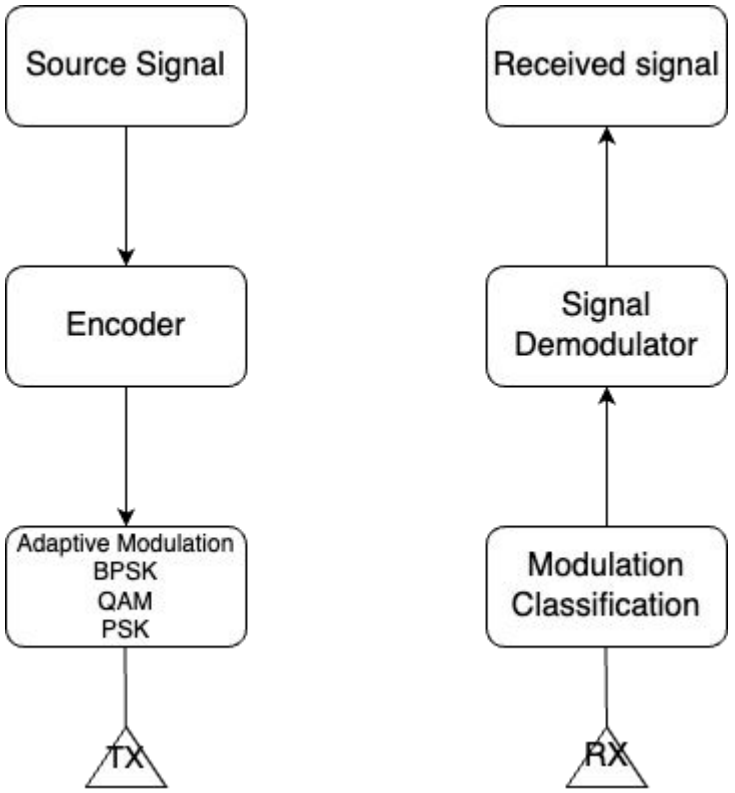
Problem Outline

- Classification of Signal Modulation in communication network
- Building lightweight ML models to feature it in resource constrained technologies
- Crucial for any vehicular communication.
- Complex models and detection time.
- Time sensitive.



T. Huynh-The et al., "Automatic Modulation Classification: A Deep Architecture Survey," in IEEE Access, vol. 9, pp. 142950-142971, 2021, doi: 10.1109/ACCESS.2021.3120419.

Application of AMC

- Vehicle to everything (V2X)
- Cognitive radios
- Satellite Communication
- IoT
- Any kind of Wireless Communication

Solution and Previous work

- CNN based AMC, [1]
- LSTM based AMC using Amplitude and Phase angle Data [2]
- Image based CNN AMC using the constellation diagram [3]
- SpatioTemporal LSTM [4]
- Data Augmentation and LSTM [5]

[1] T. O'Shea and J. Hoydis, "An Introduction to Deep Learning for the Physical Layer," in IEEE Transactions on Cognitive Communications and Networking, vol. 3, no. 4, pp. 563-575, Dec. 2017, doi: 10.1109/TCCN.2017.2758370.

[2] S. Rajendran, W. Meert, D. Giustiniano, V. Lenders and S. Pollin, "Deep Learning Models for Wireless Signal Classification With Distributed Low-Cost Spectrum Sensors," in IEEE Transactions on Cognitive Communications and Networking, vol. 4, no. 3, pp. 433-445, Sept. 2018, doi: 10.1109/TCCN.2018.2835460.

[4] J. Xu, C. Luo, G. Parr and Y. Luo, "A Spatiotemporal Multi-Channel Learning Framework for Automatic Modulation Recognition," in IEEE Wireless Communications Letters, vol. 9, no. 10, pp. 1629-1632, Oct. 2020, doi: 10.1109/LWC.2020.2999453.

[5] L. Huang, W. Pan, Y. Zhang, L. Qian, N. Gao and Y. Wu, "Data Augmentation for Deep Learning-Based Radio Modulation Classification," in IEEE Access, vol. 8, pp. 1498-1506, 2020, doi: 10.1109/ACCESS.2019.2960775.

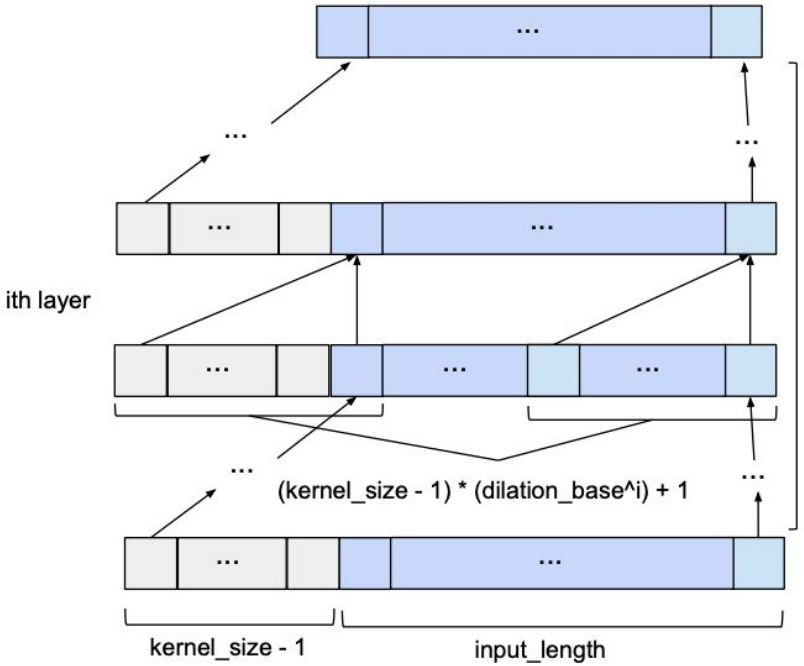
Proposed Method

- Temporal Convolutional Neural Network [6] (TCN)
- Deals with temporal details of the data
- Better than LSTM for training time and the prediction time
- Less complexity and Light weight model

[6] Colin Lea, Michael D. Flynn, Rene Vidal, Austin Reiter, Gregory D. Hager; Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2017, pp. 156-165

TCN

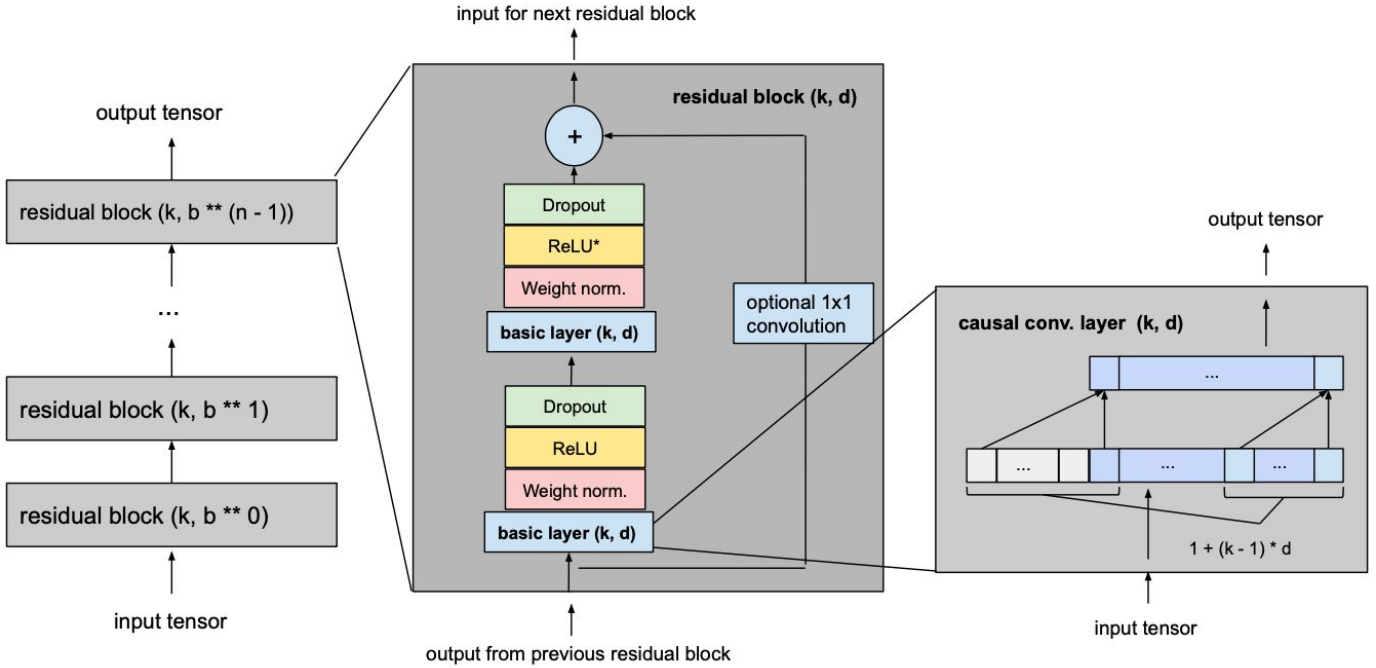
- Standard Convolutional Network with dilations
- Uses kernel and dilations to get the temporal details
- kernel is the window size of values of data point
- Dilation is the next adjacent value to be taken in one kernel



https://unit8.com/resources/temporal-convolutional-networks-and-forecasting/

Modified TCN

- Residual Block
- Deals with temporal details of the data
- Better than LSTM for training time and the prediction time
- Less complexity and Light weight model

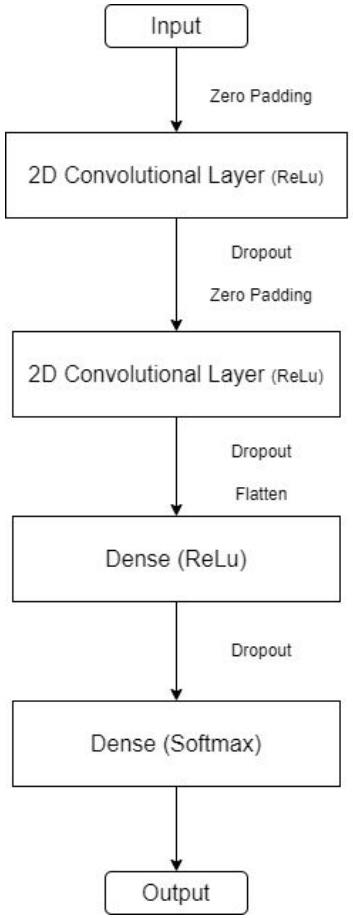


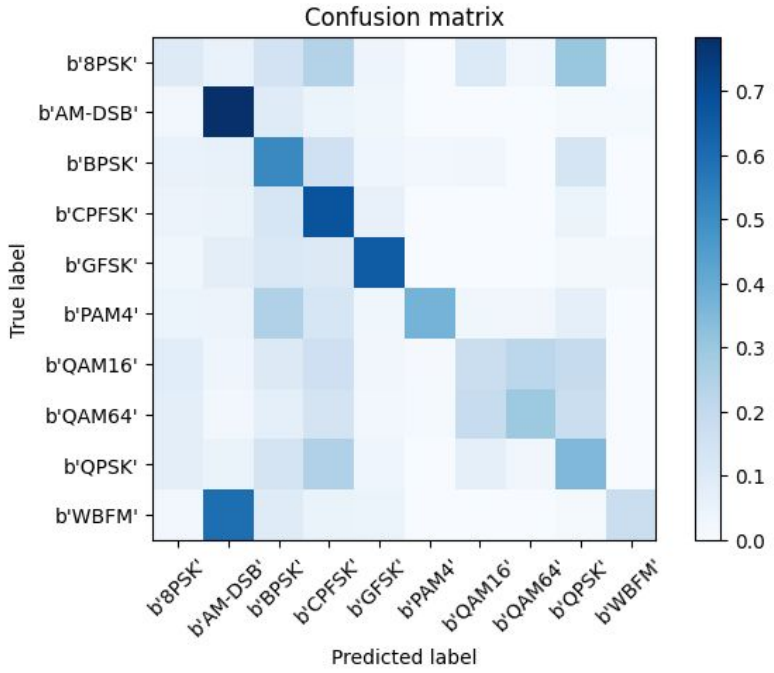
https://unit8.com/resources/temporal-convolutional-networks-and-forecasting/

Michigan Tech

CNN Performance [1]

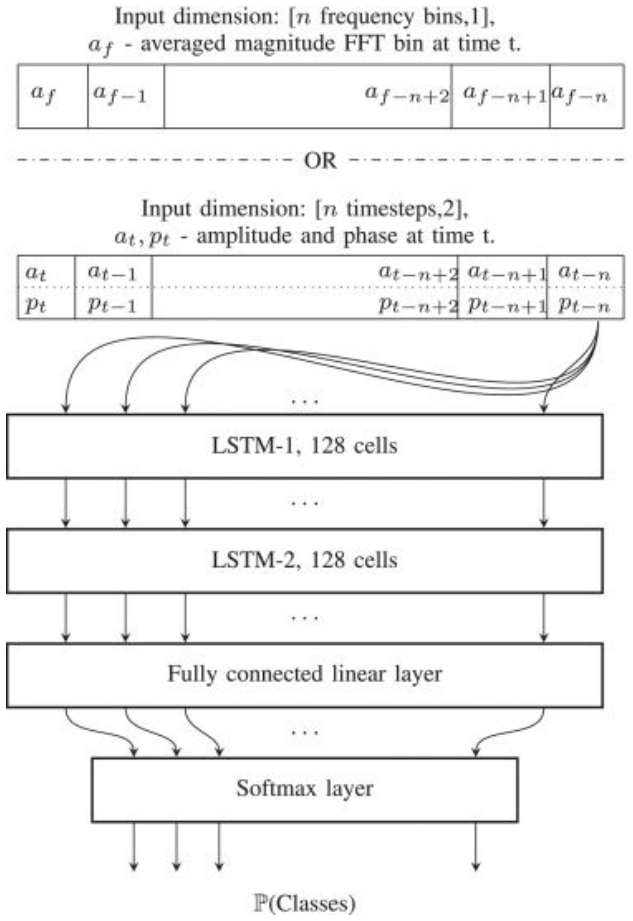
- 2 Layer Convolutional Network
- Data: I/Q Signal Data
- Overall Accuracy: 0.4090
- Max Accuracy: 0.605 at SNR = 10
- Epoch: 100
- Batch Size: 1024

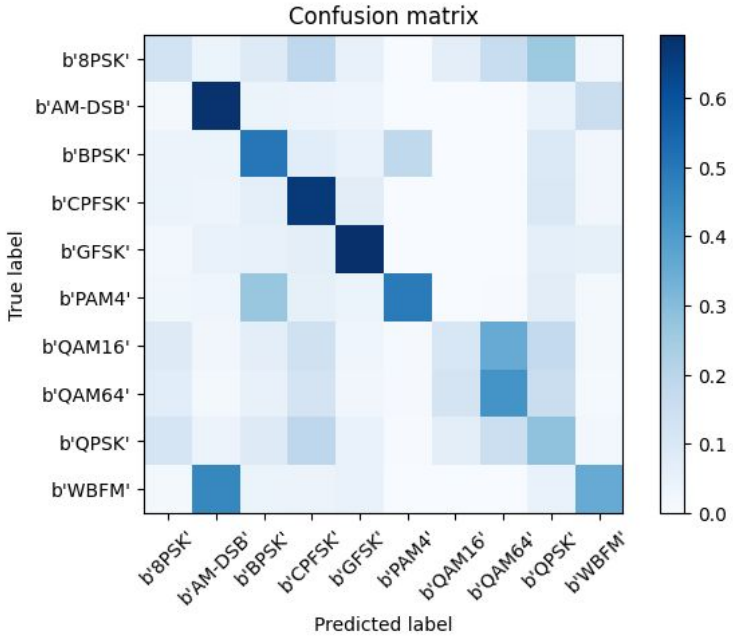




LSTM Performance [2]

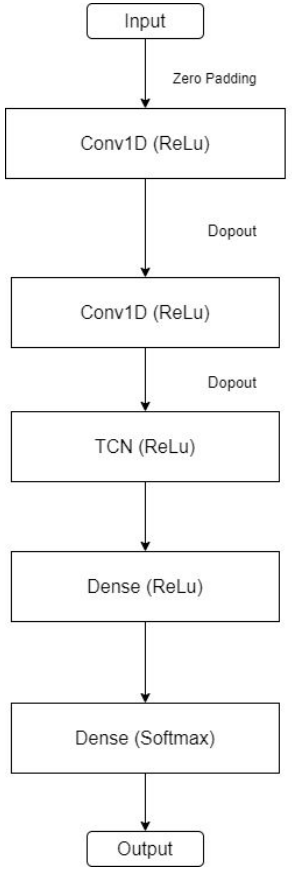
- 2 Layer LSTM Network
- Data: Amplitude and Phase
- Preprocessing: L2 Norm on Amplitude
- Accuracy : 0.433
- Max: 0.646 at SNR 2
- Training Time:
- Epoch: 100
- Batch Size: 400

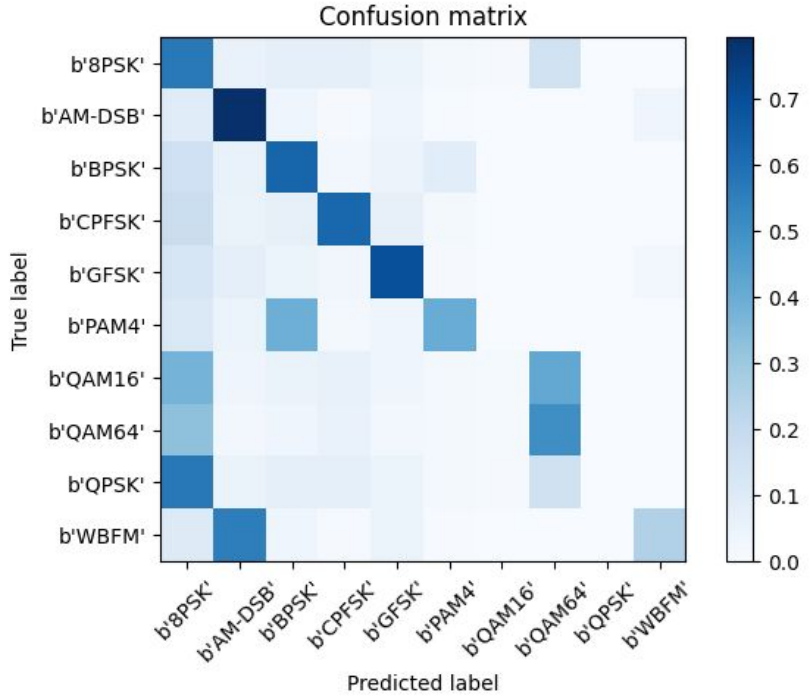




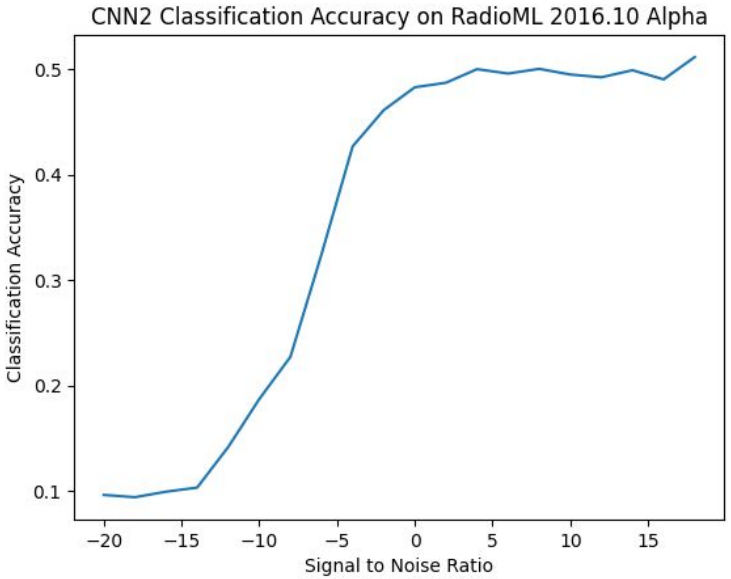
ConvTCN Performance (proposed)

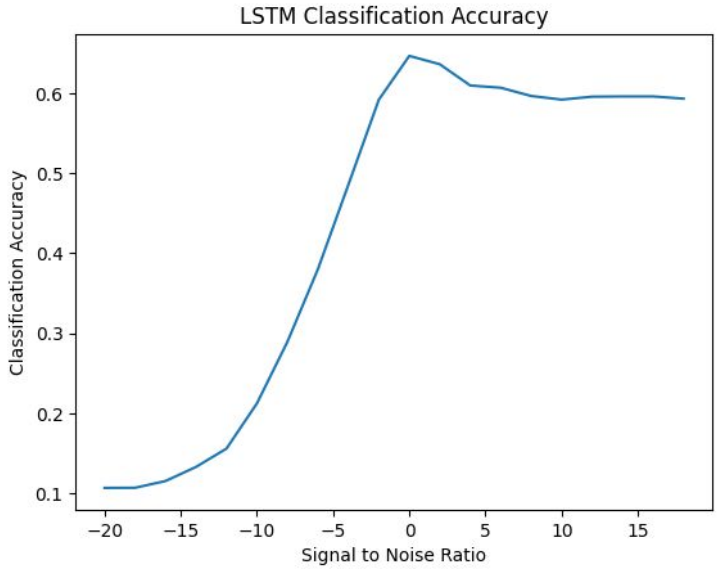
- 2 Layer Conv 1D Layer; 1 Layer TCN
- Data: I/Q Samples
- Overall Accuracy : 0.4486
- Max Accuracy: 0.648 at SNR = 2
- Epoch: 300
- Batch Size: 400

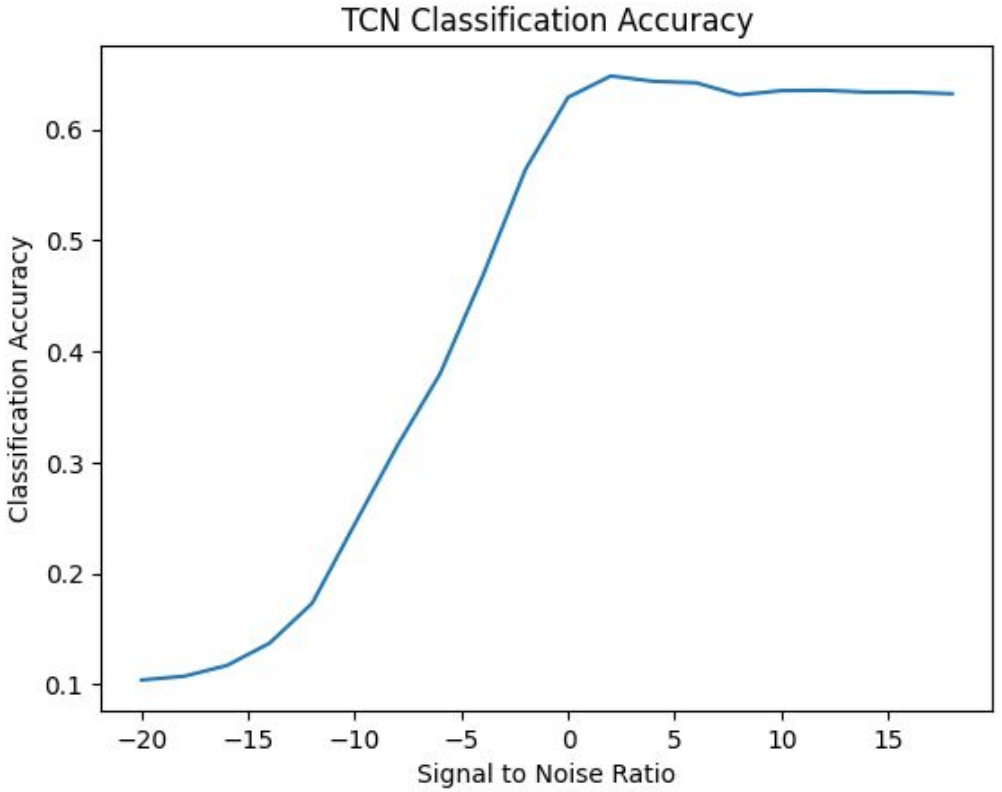




Result Comparison







Future Work

- Image based signal modulation classification.
- TCN using augmented data
- Spatiotemporal TCN
- TCN using Polar form of signal
- Focus on V2X modulations with Low signal to noise ratio