Error-Resilient Compression: Using Deep Learning and Polar Coding to Improve Satellite Communication

Mission for Education and Multimedia Engagement Satellite (MEMESat-1) – Let's Go To Space Inc.

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Overview

MEMESat-1 is a flying transceiver for the amateur radio community with a packet data rate of 9600 baud (*Lassiter et al*). This severely limits the amount of data that can be transmitted on each pass by a ground observer, hence, compression must occur. Due to the general similarity of the expected payload data (such as *Figure 2*), we hypothesize that compression via deep learning is the best approach.

Data Generation

Roughly 4000 memes were collected by web scrapping Reddit and generous donations from the students at the University of Georgia. After being collected, certain memes, such as those with less family friendly undertones, are stripped from the dataset to minimize the chance of inappropriate reproduction of learned content. Once prepared, images were resized to 512x512 prior to input to the model as the network requires a fixed size input.

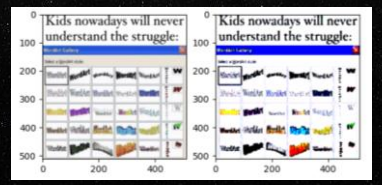
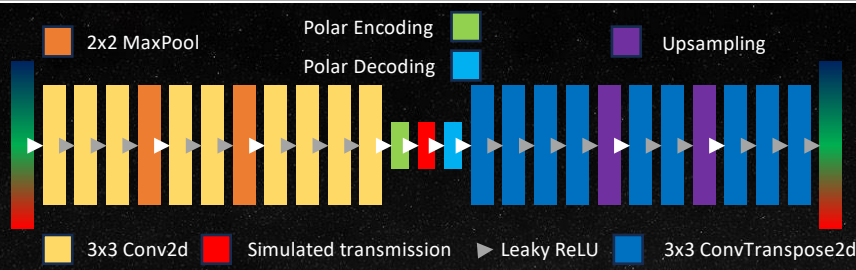


Figure 1: An example of a meme after running through the pipeline which demonstrates a complex variety of fonts. It should be noted that this is a learned image.

Figure 2: Example payload data (*Lassiter et al)*



Network Architecture

The network is built using primarily convolutional layers with small kernel sizes to better learn fine edges that are apparent within text in memes. Hyperparameters (batch size, # of epochs, and learning rate) were optimized using a grid search technique, training several different models with differing hyperparameters and comparing each against each other.

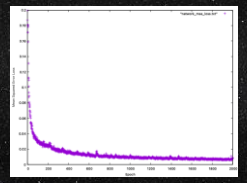


Figure 4: Mean Squared Error (MSE) loss of network

Future Work

Beyond refining the network, packetization of the bits within the latent space of the network will need to be implemented in order to produce a 'radio ready' encoded output. The model will also be continuously training on images submitted by the community and a web scrapper so that it can keep up with cultural trends. Proper testing with radio transmission between the encoding and decoding of the images during training will also be done to better learn actual transmission noise. Finally, the pipeline will need to be visible to both the user-facing front end for MEMESat-1, the Bulletin Board System, and COSMO, the ground station for the Small Satellite Research Laboratory, where MEMESat-1 is produced. Once launched, the code will be made open source.

Polar Coding

Polar coding is an error correction technique that achieves the capacity of binary input discrete memoryless channels (B-DMC), proven by Erdal Arikan in 2008 (*Arikan*). This method involves channel polarization, a process where multiple independent channels are transformed into an equivalent number of 'polarized' channels, some having high reliability and some having very low reliability. The encoding phase involves transmitting the important data ('information' bits) through the high-reliability channels, and known 'frozen' bits through the low-reliability channels. At the receiver end, the original message is reconstructed using a decoding algorithm based on calculating probabilities, given the received bits and the knowledge of the frozen bits.

Figure 5: A visualization of the creation of 'good' and 'bad' bit channels

References

- C. Lassiter, M. Starks, C. Versteeg, S. Whilden and D. R. Mishra, "The Mission for Education and Multimedia Engagement: Breaking the Barriers to Satellite Education," 2023 IEEE Aerospace Conference,
- Arikan, E., "Channel polarization: A method for constructing capacity-achieving codes for symmetric binary-input memoryless channels".

Acknowledgements

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