Hackathon NATO IST

PRESENTED BY
Afonso Baixo | Gabriel Santos | Henrique Freitas

Ctrl + Flight Drone Detection

Model development for drone detection and classification

>

Datasets Used

DroneRFb-spectra:

- 24-class drone (0-23 directories)
- npy files (time bins x frequency bins)

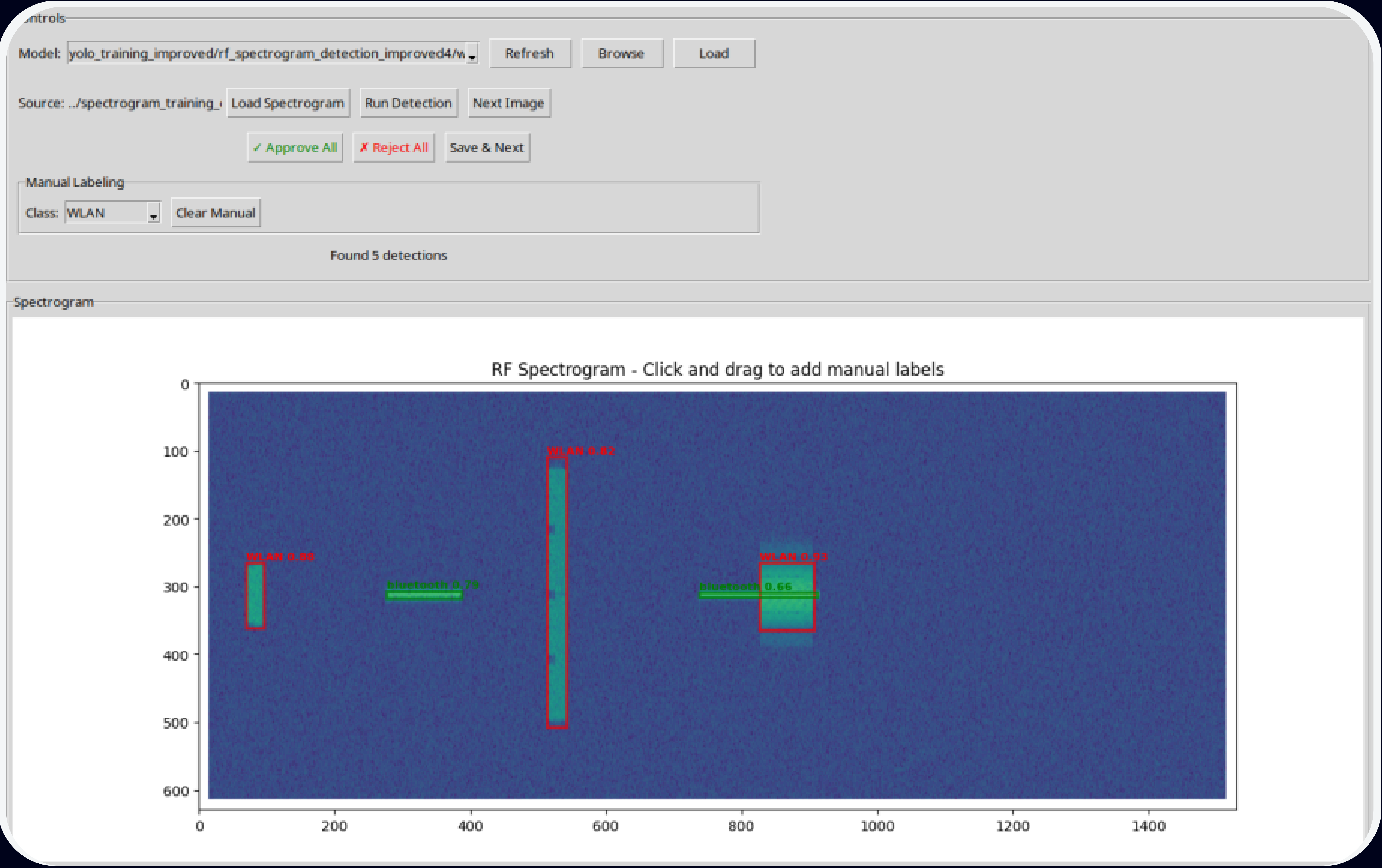
Spectrogram_training_data_20220711

- binary .packet containing complex IQ samples;
- merged packets; single packets; results folder (.png, .txt,.packet, .csv)

DroneRF dataset:

- Raw RF signals in CSV format (signal type, power level)
- Naming patters: ex: 11000 (specific drone) and H or L (power level)
- Session ID number

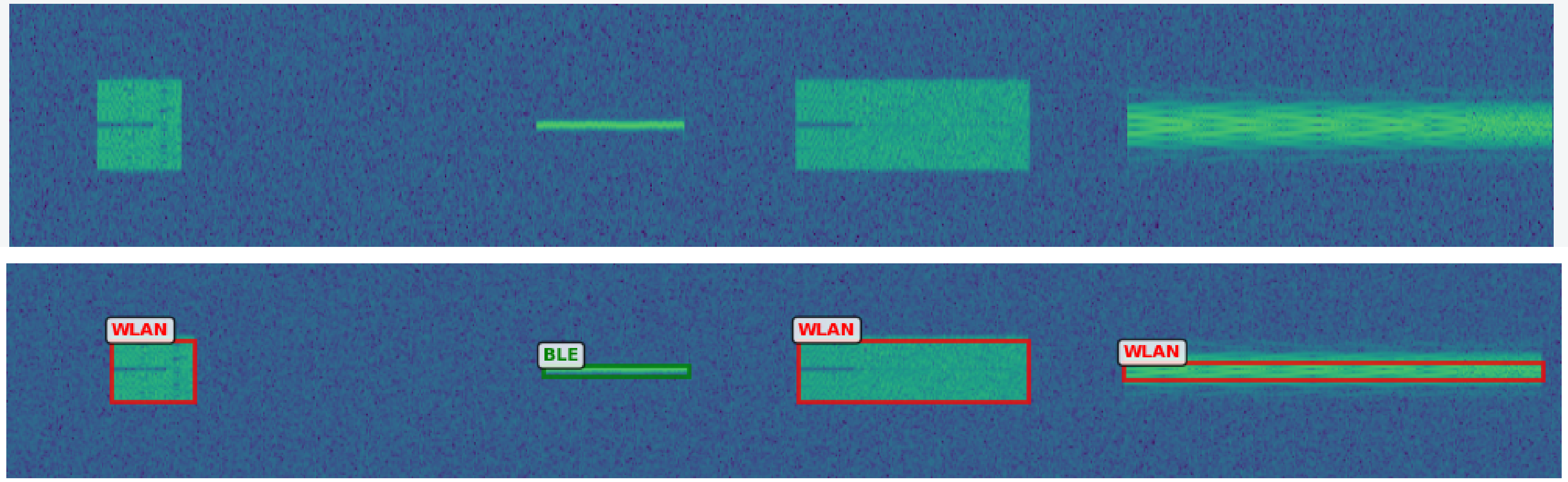
Dataset Labelling



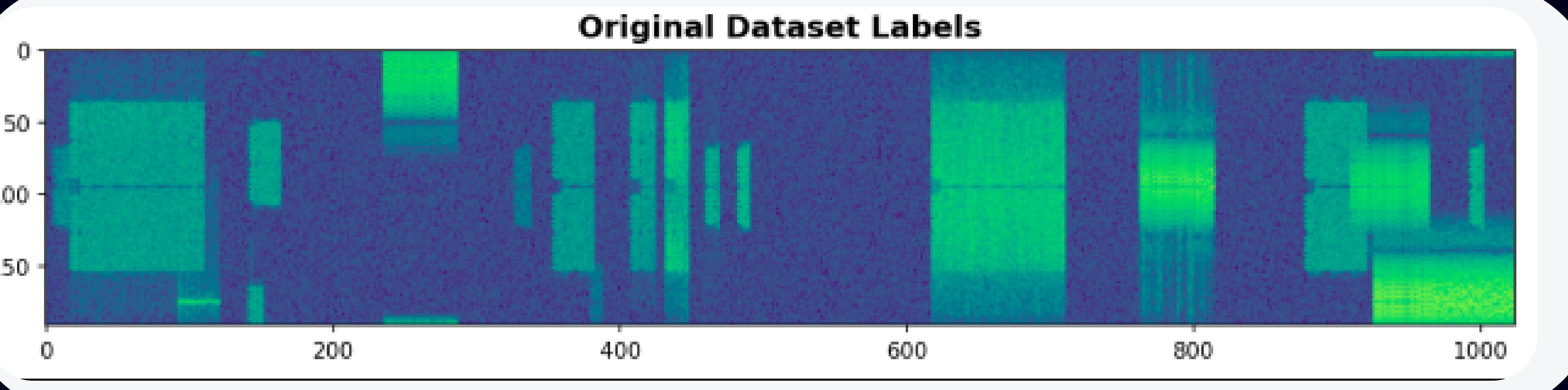
Auto Labelling

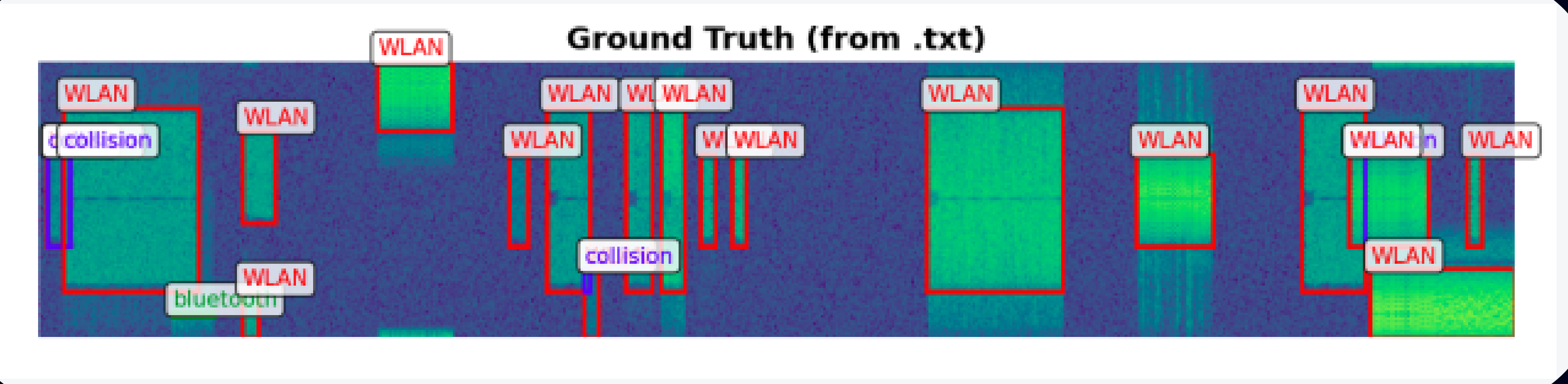
1. **Label-Based Training**

- Started with pre-labeled spectrograms (YOLO format)
- Each label file linked to a spectrogram
- Used directly for training YOLOv11 on know classes

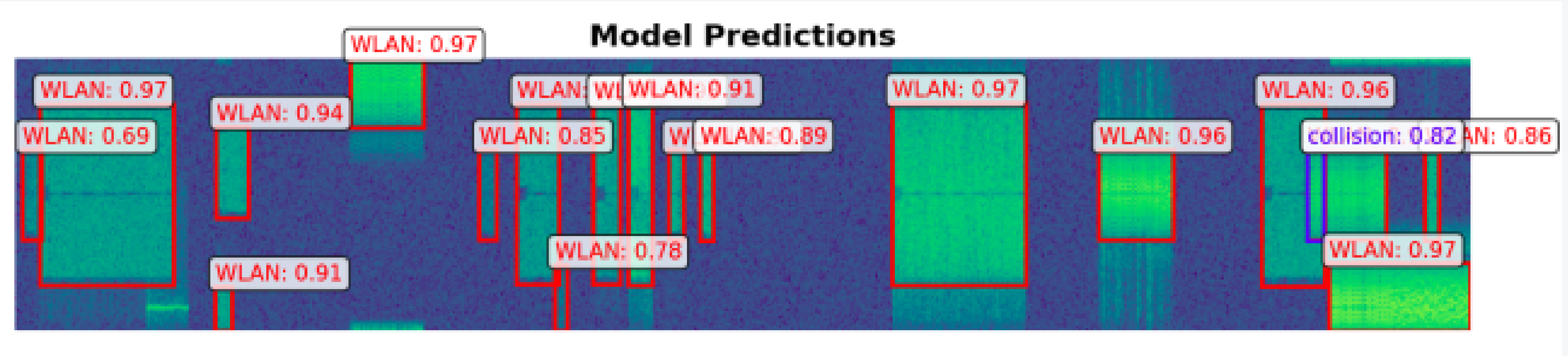


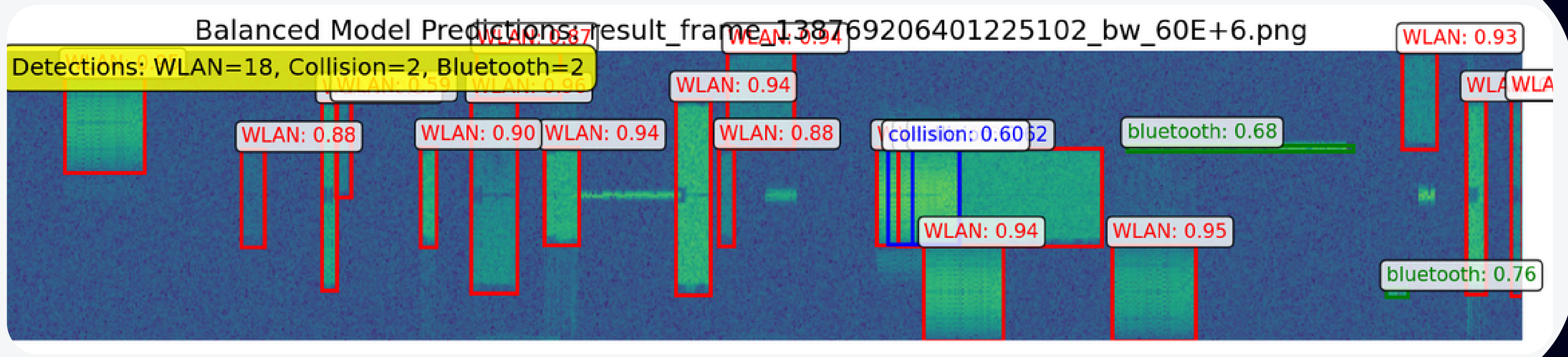
Dataset Labelling





Predictions





Experiments

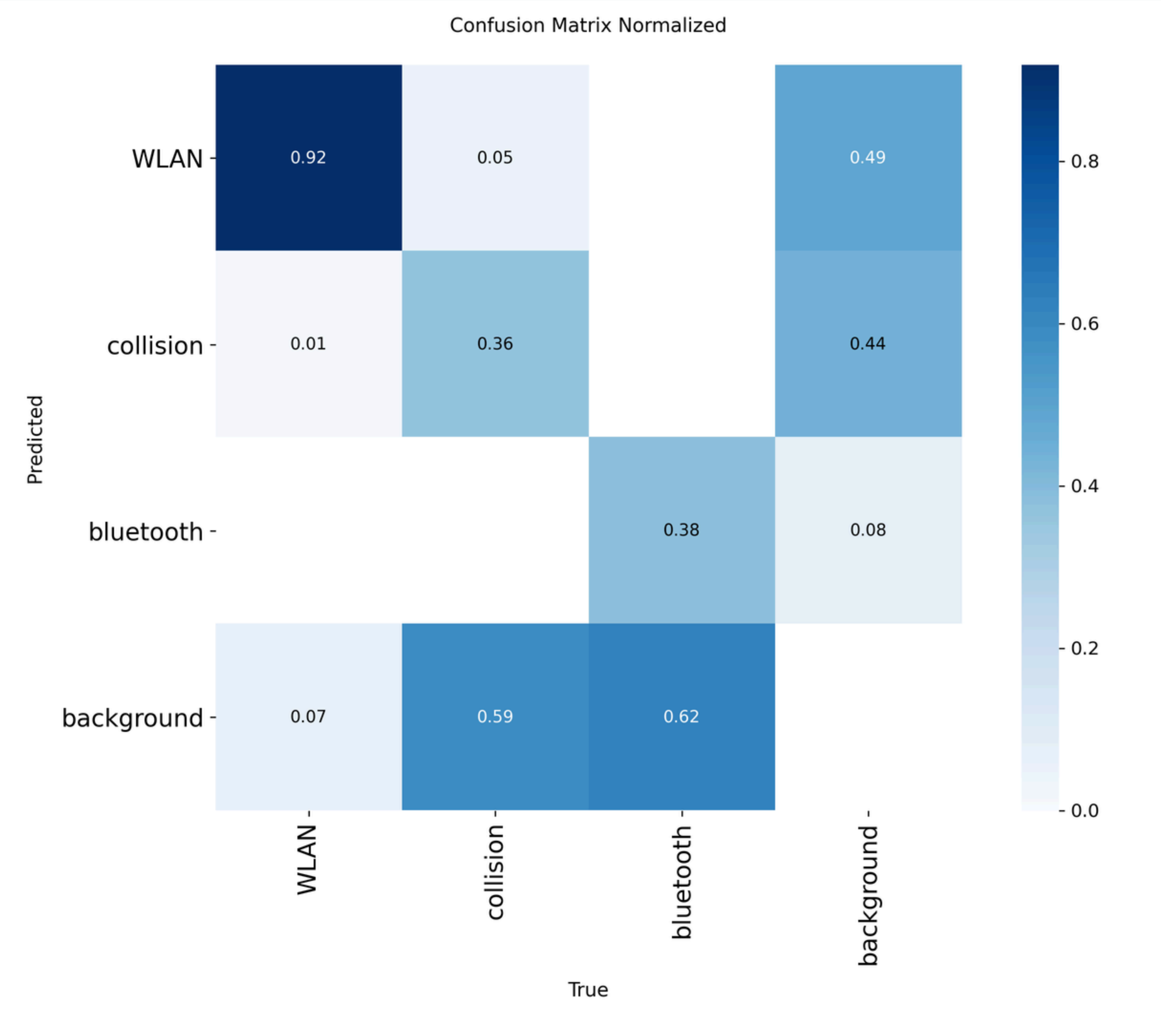
YOLOv8

- Used YOLO for visually classifying in between 3 classes: BLE, WLAN, colisions.
- Trained with 200 epochs
- Batch size 16
- Higher classification loss weight for class imbalance (BLE signals)

Why choose YOLO

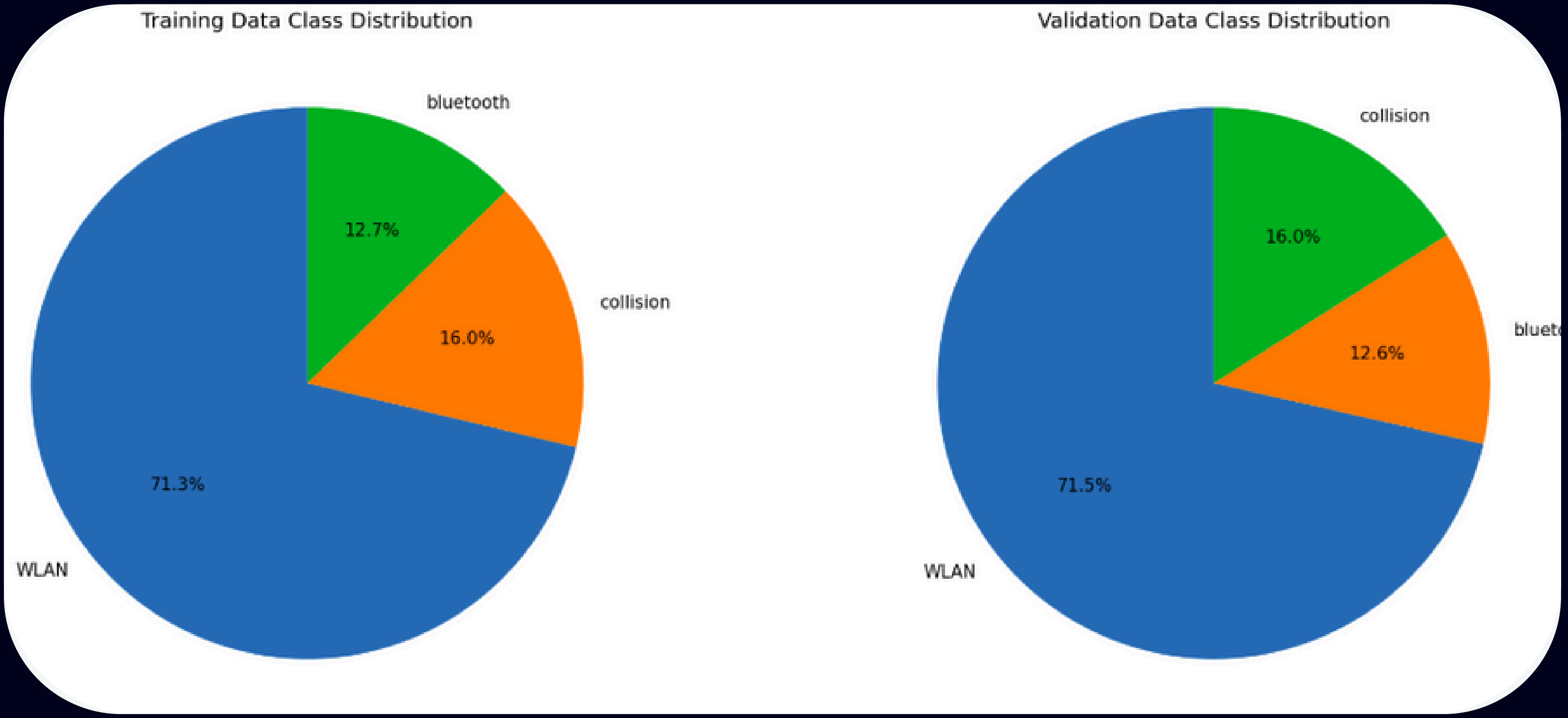
- Analyzing frequencies visually on a spectrogram
- Dataset already with labelled images in the .txt format, perfect for YOLO

YOLO Results



Conclusion

- Worse at detecting BLE signal (imbalanced dataset)

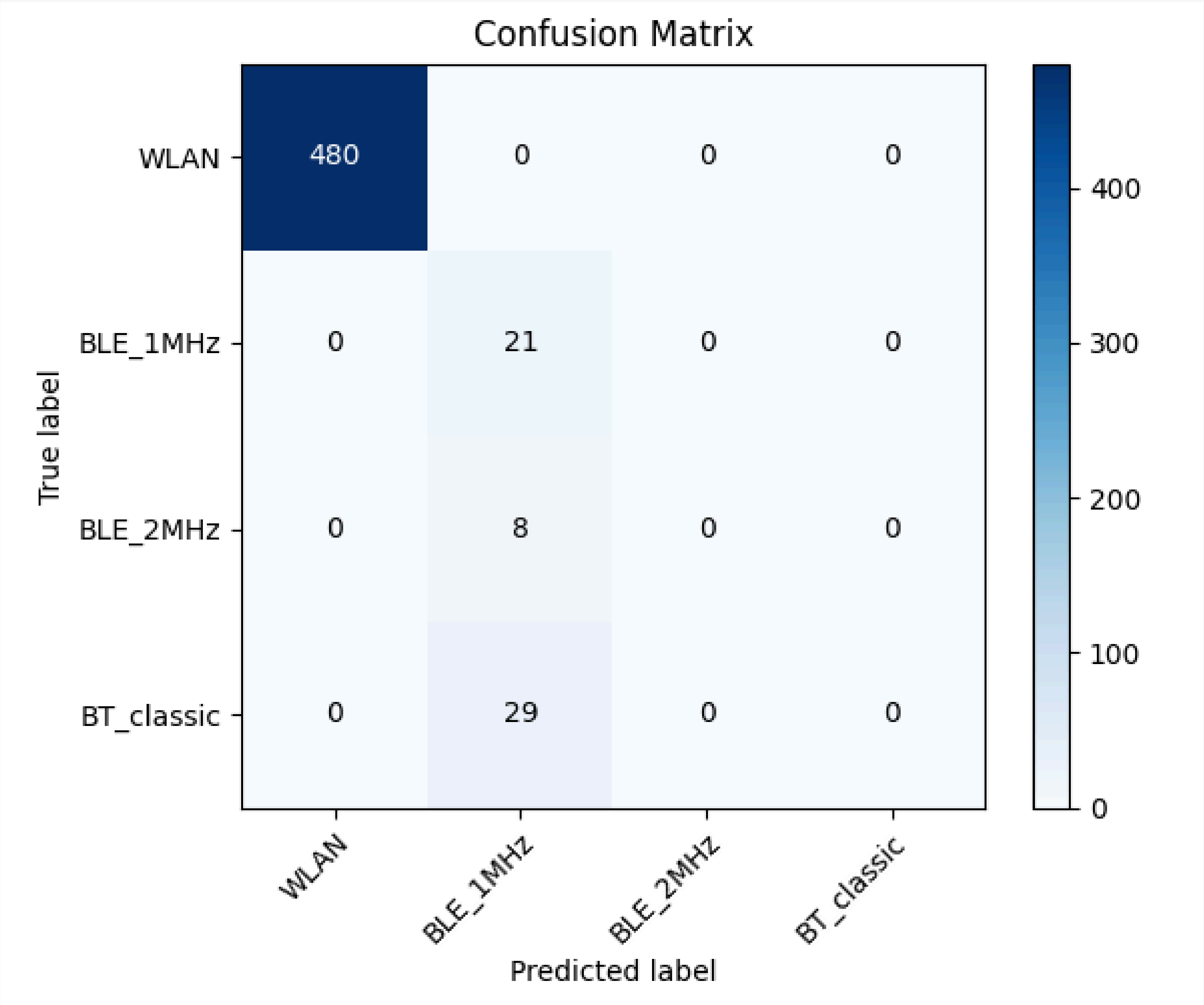


RNN Architecture

RNN (Recurrent Neural Networks) is a set of DNN that is great for processing sequential data, and for time-series analysis.

Why choose RNN?

- Signal variation dependency over time
- Same bandwith different patterns
- Lighter processing pipeline compared to vision based models



RNN Results

Conclusion

- Faster Pipelines
- High expectations for Drone Identification
- Expectancy of a high accuracy with better sampling techniques

Drone Classification

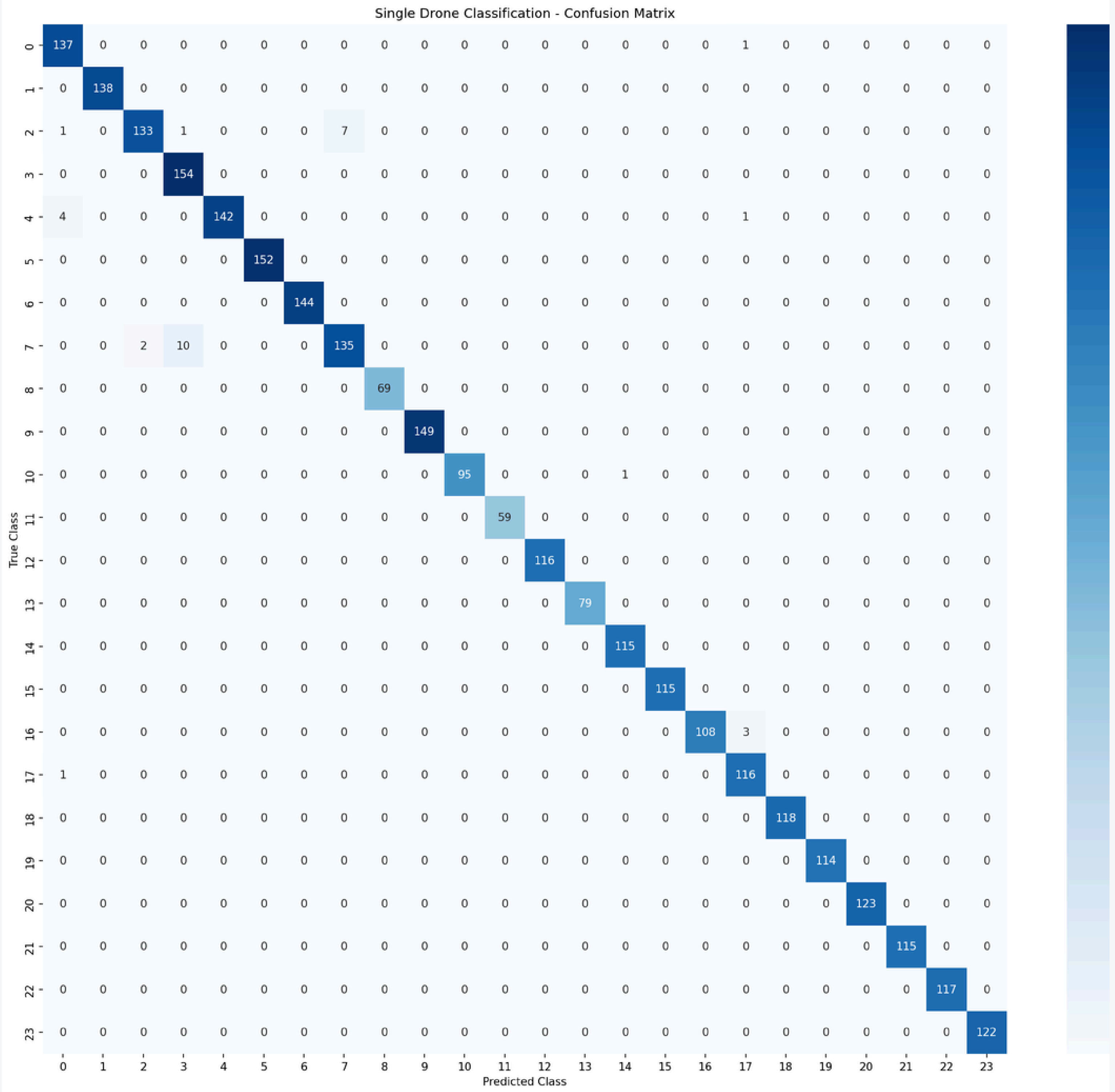
CNN Architecture

We opted for a **Convolutional Neural Network Architecture** to try to effectively train a model for drone classification.

- 32 to 512 filters
- 3x3 kernel size
- Dropout 25%

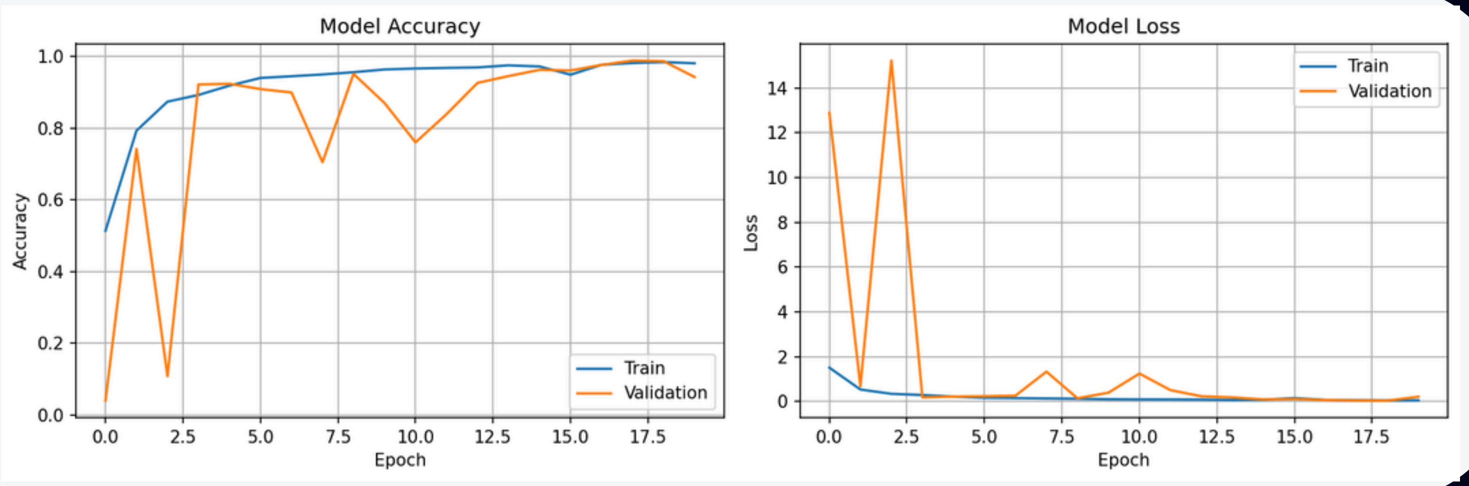
Why choose CNN?

- Good for general image recognition patterns



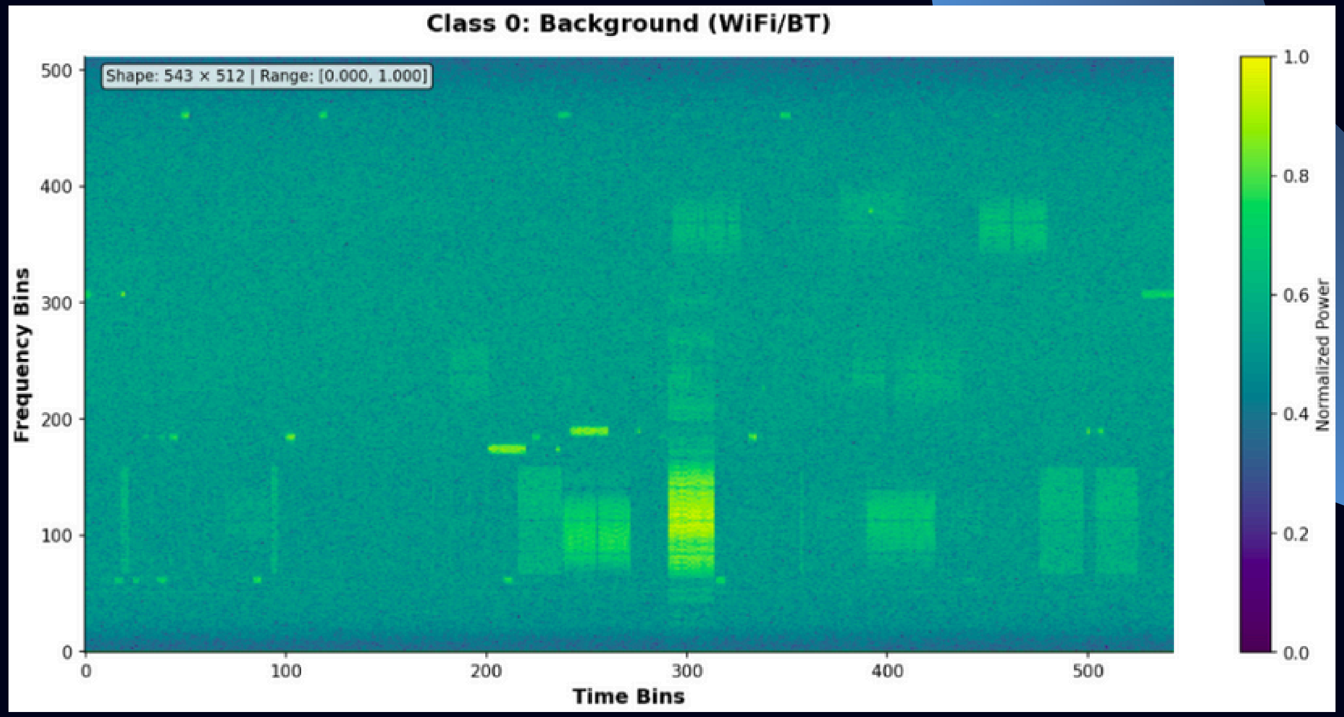
Conclusions

- Very Good Drone Classification and Identification
- Accuracy: ~96%

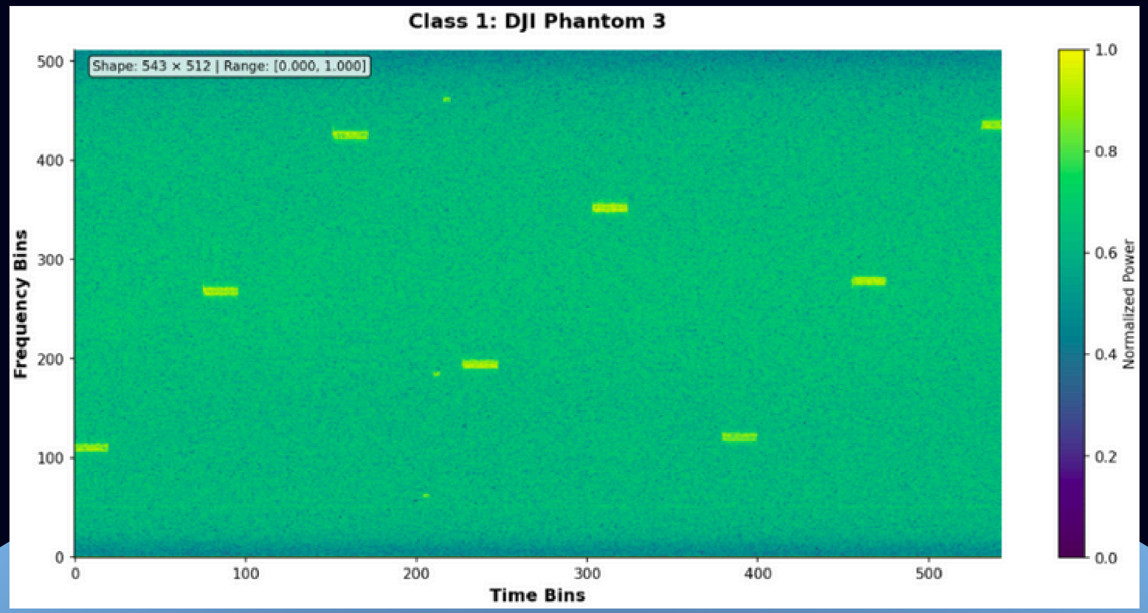


CNN Results

YOLO Architecture

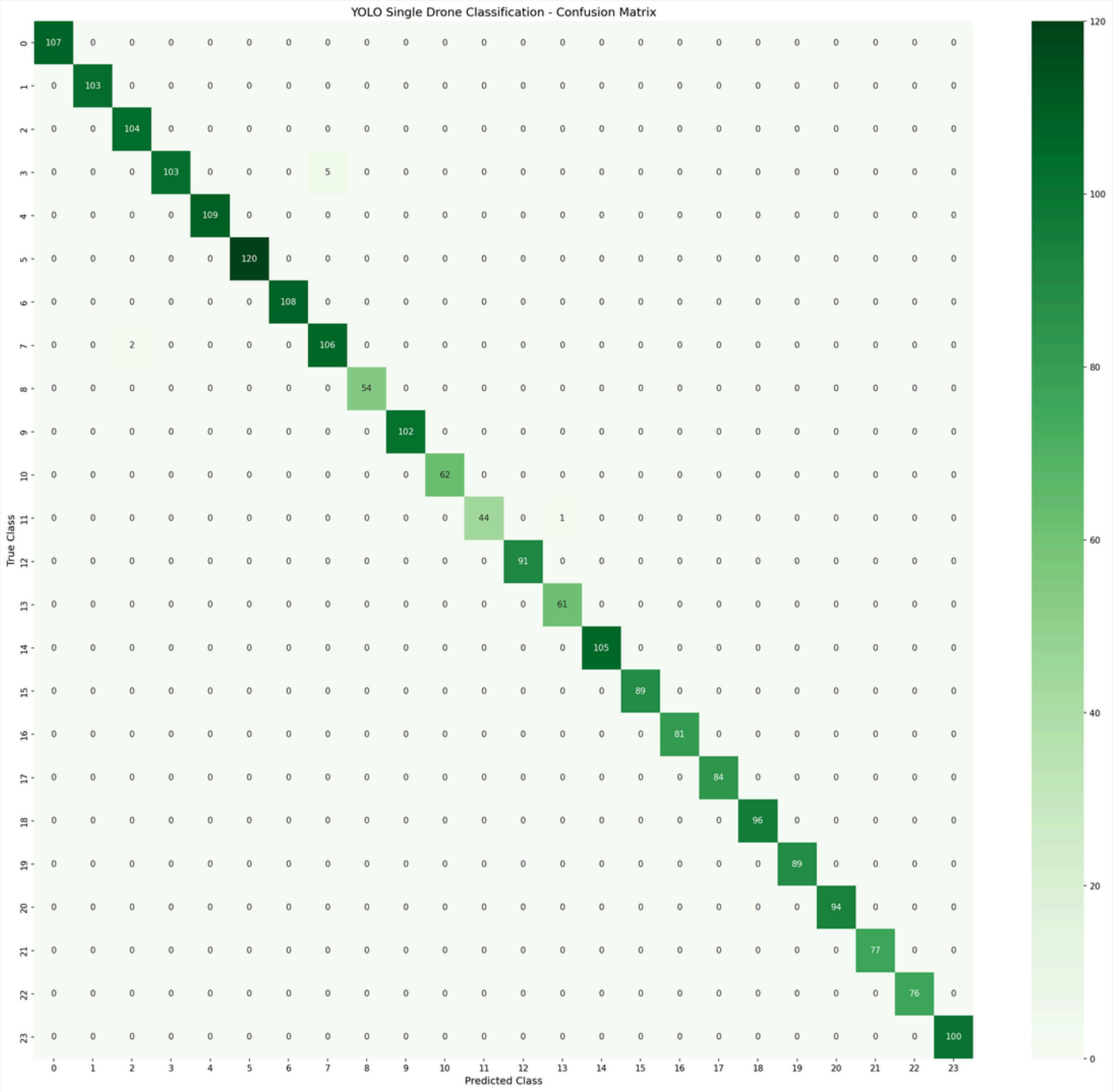


- For the YOLO attempt (visual model) we used YOLOv11, trained with CUDA
- We transformed the .npy into labelled spectrograms for the 23 different drones using DroneRFb (single drone classification)
- Measuraments, crossentropy loss, accuaracy, precision, recall
- Dataset 70 -15 - 15



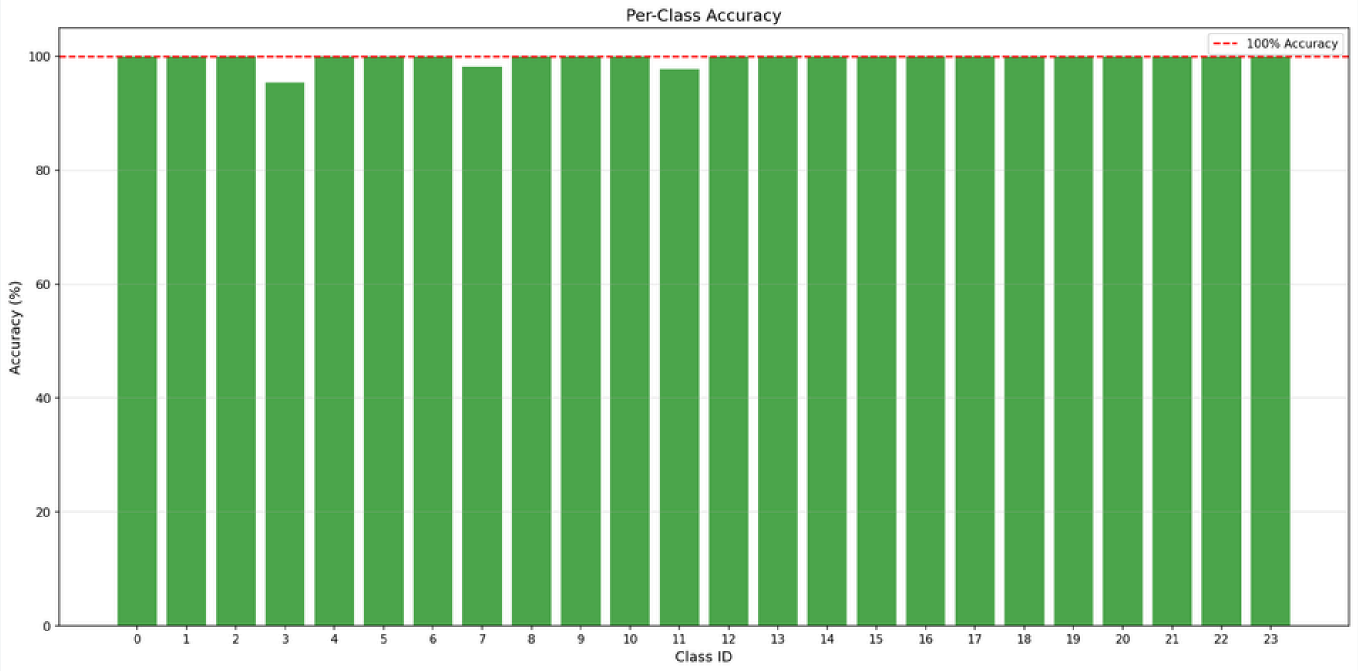
Why choose YOLO

- Good visual model
- Multi-layered classification
- Good testing results



Conclusion

- Very Good Drone Classification and Identification
- Accuracy: ~99%



YOLOv11 Results

Road Bumps

- Dataset Volume
- Different signal sample formats
- Computing power
- Interpretation difficulties

Future Works

- Introduction of the “Drone Remote Controller RF Signal Dataset”
- BiLSTM Adaptation for Drone Classification
- Develop a continous Drone classification pipeline

References

Datasets

- SunRISE / Spectrogram Dataset
- S3R - Synthethic RF Spectrogram Repository (DaftJun)
- DroneRFb Spectra Dataset
- MATLAB AI Spectrum Sensing Dataset
- Mendeley Dataset - RF Signal Classification with CNNs
- DroneRF Dataset (Al-Sa'd et al.)

Papers

- **"Combined RF-Based Drone Detection and Classification"** *Basak et al., 2022*
- **"RF-based Drone Detection and Identification using DL Approaches"** *Al-Sa'd et al., 2019*
- **"Prediction-Based Spectrum Sensing for Cognitive Radio"** *Rojas et al., 2025*
- **"Open Set Learning for RF-Based Drone Recognition"** *Yu et al., 2024*
- **"SMNet: Multi-Drone via Spectrograms"** *Zhao et al., 2025*
- **"Spectrogram Data Set for DL-Based RF Frame Detection"** *Wicht et al., 2022*
- **"Enhancing UAV Network Security with GANs"** *Huang et al., 2025*
- **"Deep Learning for RF Fingerprinting: A Massive Experimental Study"** *Jian et al., 2020*