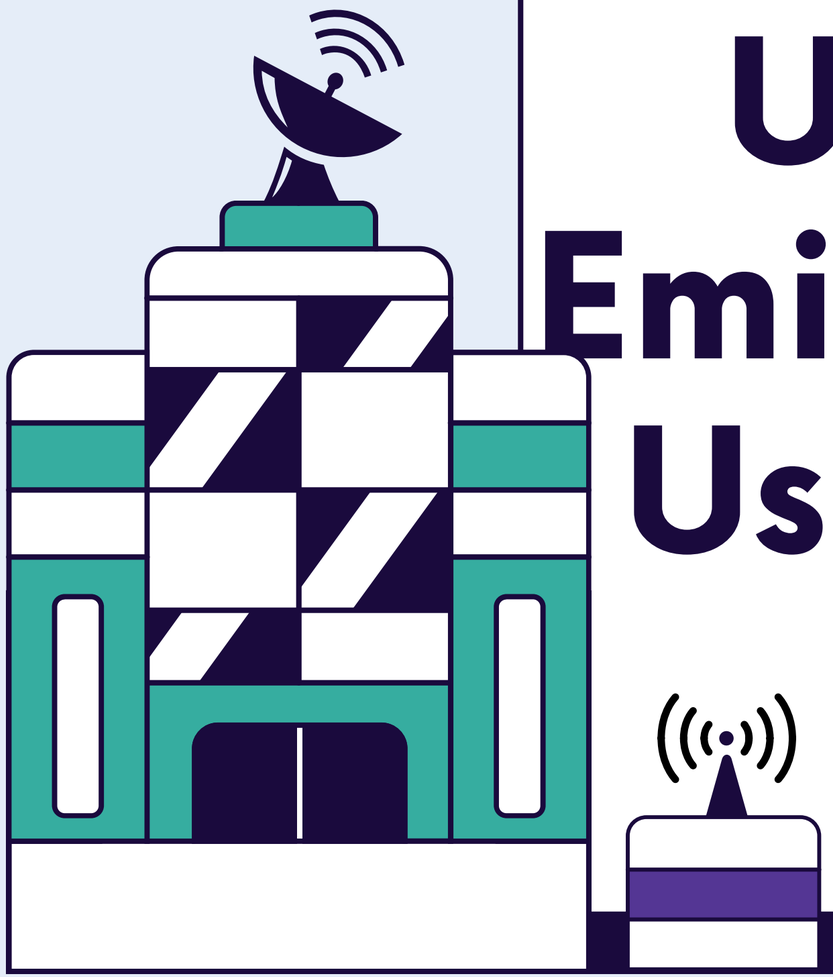
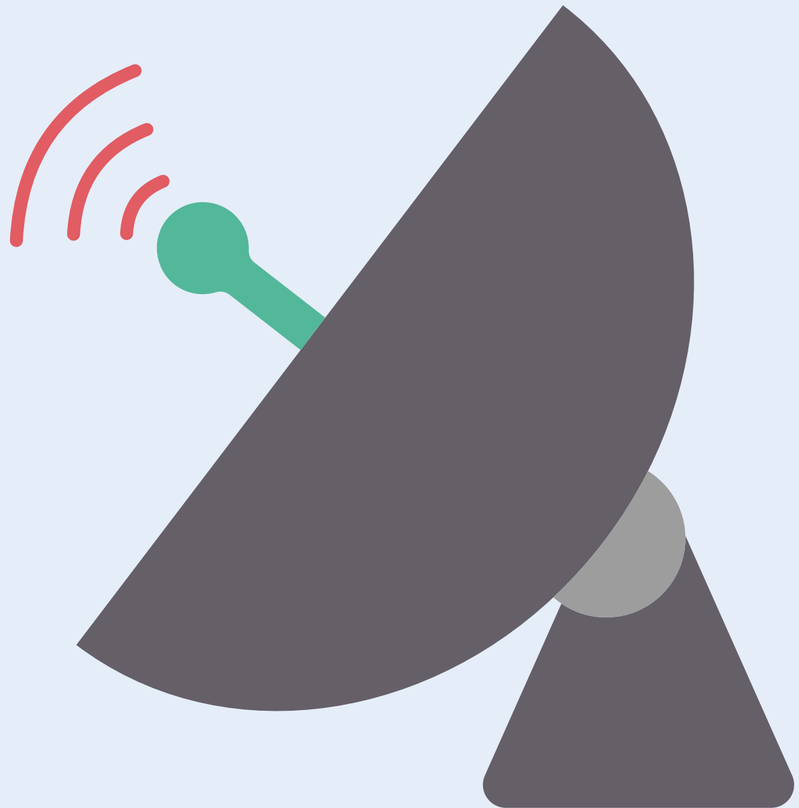
Radar Recognition System

Unknown Radar Emitter Recognition Using ResNet And Clustering



What is a Radar?

1. Radar stands for “Radio Detection and Radiation”.
2. It is a detection system that uses radio waves to determine the range, angle and velocity of objects.
3. It can detect aircrafts, ships, guide missiles, motor vehicles and weather formulation.



APPLICATIONS OF RADAR SYSTEM

- AVIATION
- MILITARY
- MARINE
- METEOROLOGY
- AUTOMOTIVE
- SPACE EXPLORATION

CHALLENGES OF UNKNOWN RADAR SIGNAL

Security Threats: Unidentified radar signals could indicate the presence of potentially hostile objects.

Air traffic Management:unknown radar signals can interfere with efficient management of aircraft, increasing the risk of midair collisions.

Electronic Warfare: Adversaries may use unknown radar signals for electronic warfare tactics such as jamming, disrupting communication and navigation.

Environmental Monitoring: unknown signals can generate false alarms or inaccurate readings.

PROBLEM STATEMENT

- In modern radar signal analysis, the identification of unknown radar emitters poses a significant challenges due to the limitation of traditional methods.
- To address these challenges, our project aims to leverage machine learning techniques to effectively identify and classify unknown radar emitters, contributing to advancements in defense, security, and airspace management.

ABSTRACT

- This project aims to develop an advanced system using machine learning techniques to accurately identify and classify unknown radar emitters, crucial for defense, security, and airspace management.
- It employs a comprehensive Python-based tech stack, to manage the data pipeline, feature extraction, and model training, aiming to enhance emitter recognition standards and improve security capabilities in military and civilian domains.

EXISTING SYSTEMS

Template Matching:

- Traditional template matching methods struggle to keep up with the complexity and flexibility of modern radar systems, leading to inaccuracies in radar emitter recognition.

Statistical Methods:

- Conventional statistical methods, such as histograms, are inadequate for handling the variability and intricate signal patterns introduced by advanced multi-function radars (MFR).

DATASET

Signals:

- Raw radar signals represented as 3D arrays.
- Shape: (532,480 samples, 1024 time steps, 2 components)

Labels:

- Indicates radar emitter types or modes for each signal sample.
- Shape: (532,480 samples, 24-dimensional label vector)

Signal-to-Noise Ratios (SNRs):

- Reflects the quality of radar signals.
- Shape: (532,480 samples, 1 SNR value)

CRUCIAL PARAMETERS

- Pulse Amplitude
- Pulse Width
- Carrier Frequency
- Pulse Repetition Interval
- Angle Of Arrival

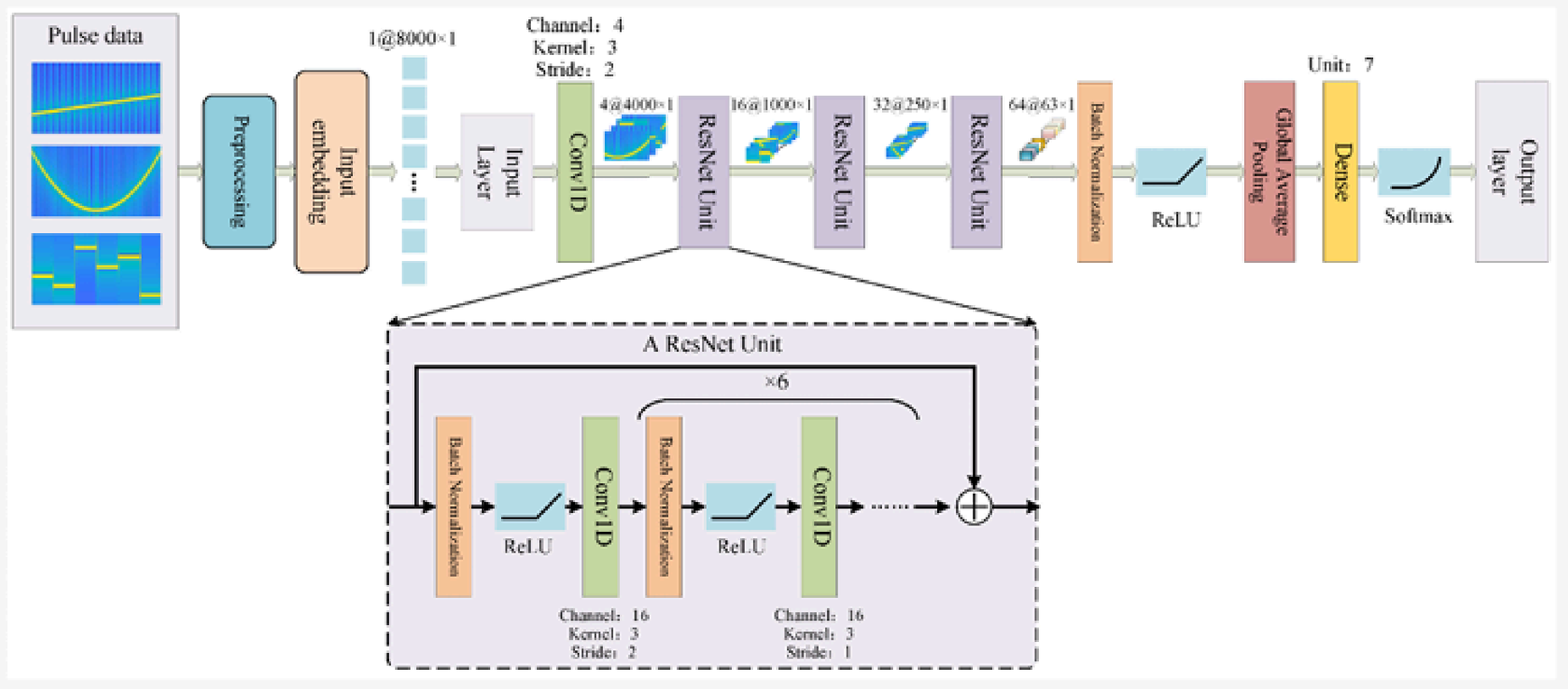
SYSTEM ARCHITECTURE

The system architecture for radar signal recognition integrates a combination of ResNet and K-Means clustering.

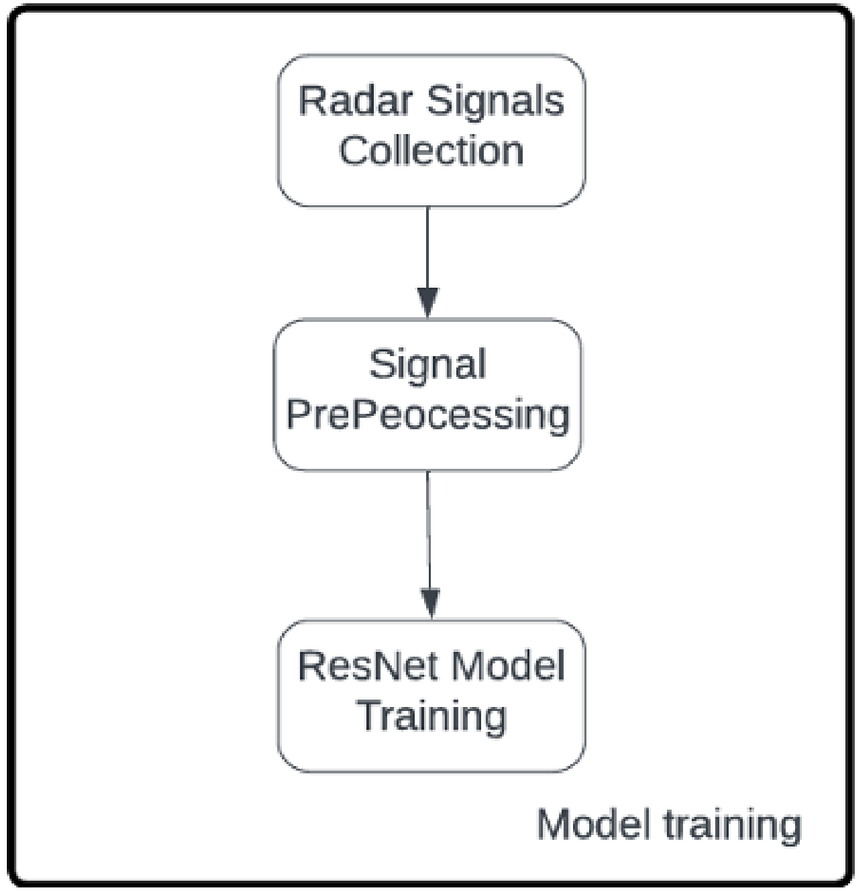
The process is divided into three main stages:

- Model Training
- Clustering of Features
- Recognition of Signals

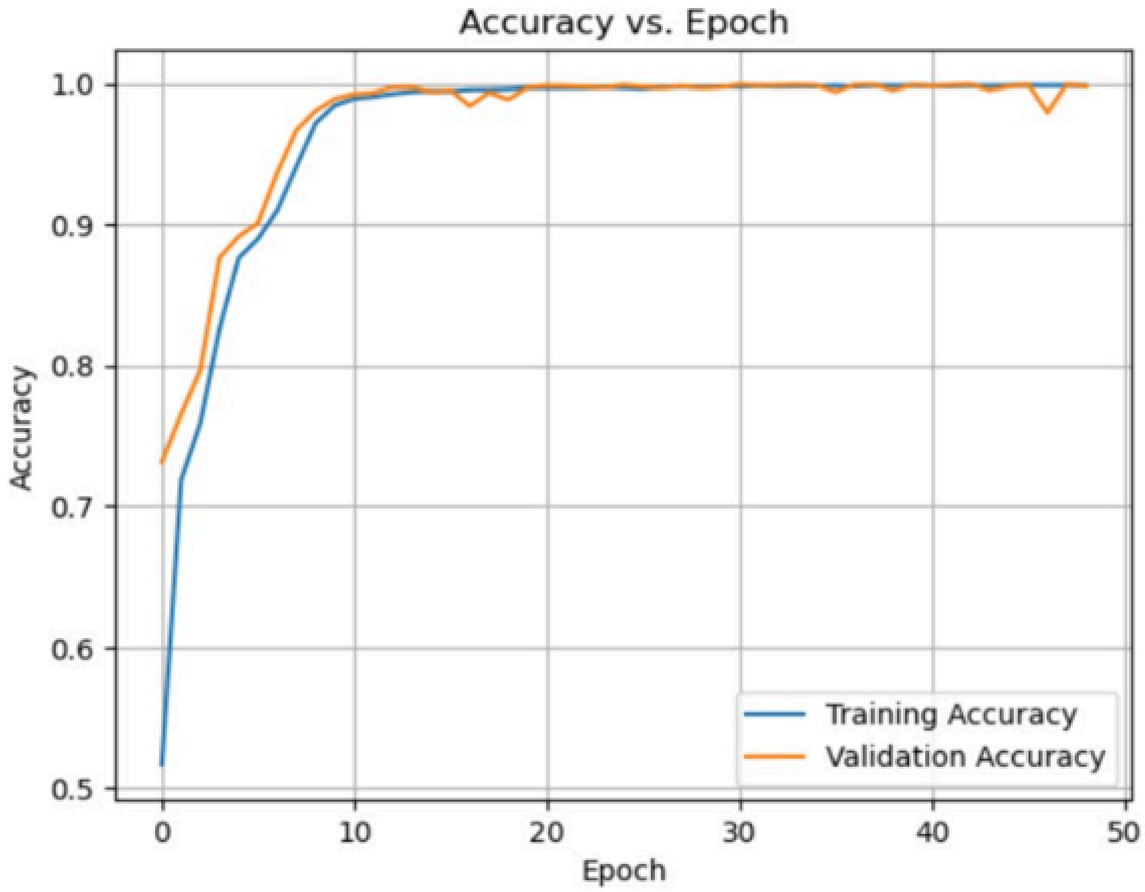
ResNet Architecture



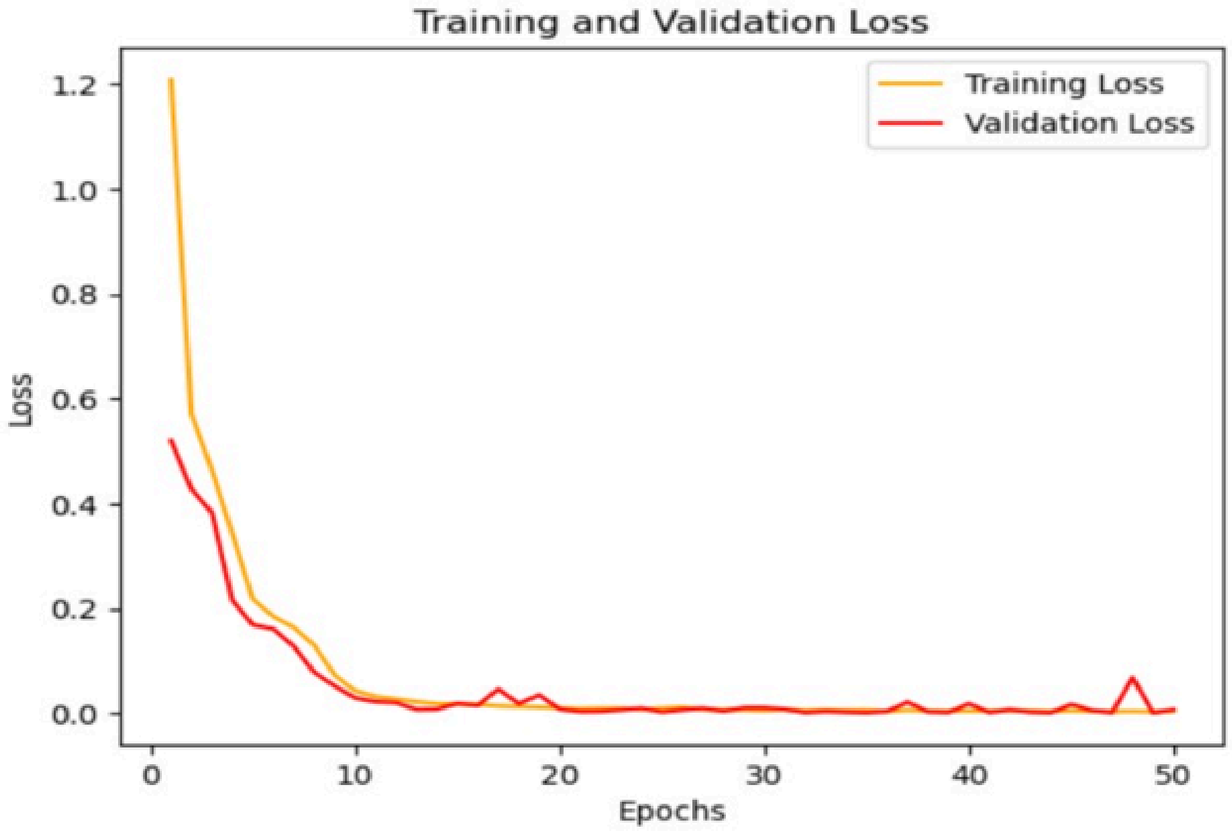
MODEL TRAINING



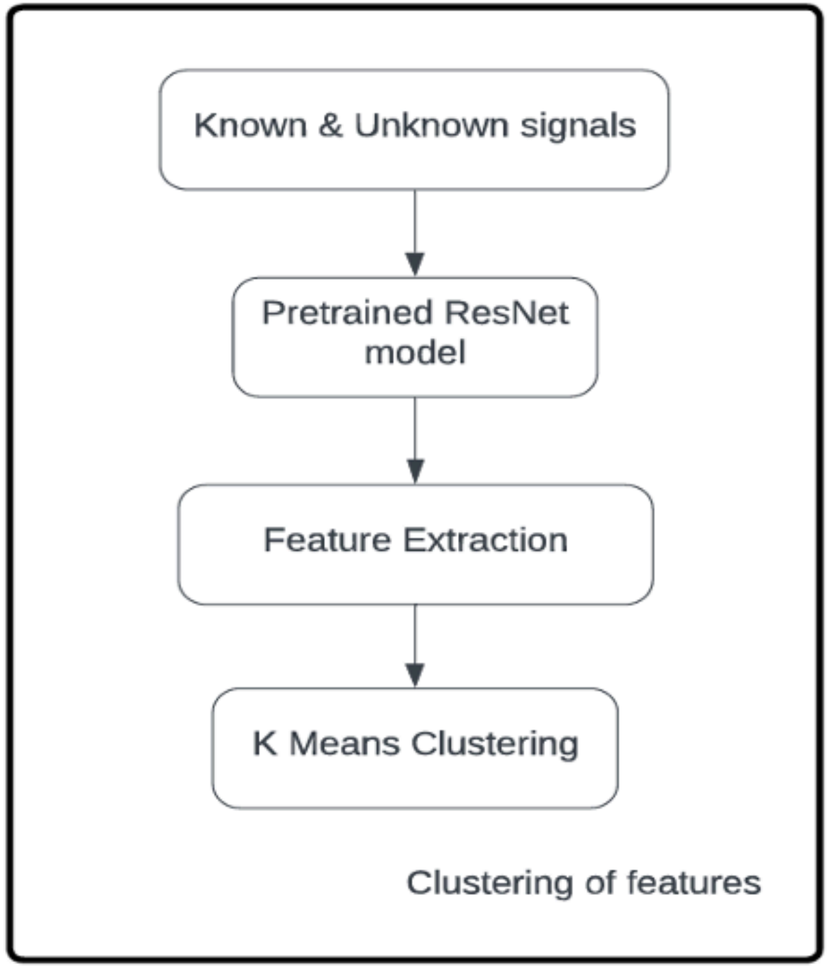
Accuracy vs Epoch Analysis



Training and Validation loss Analysis

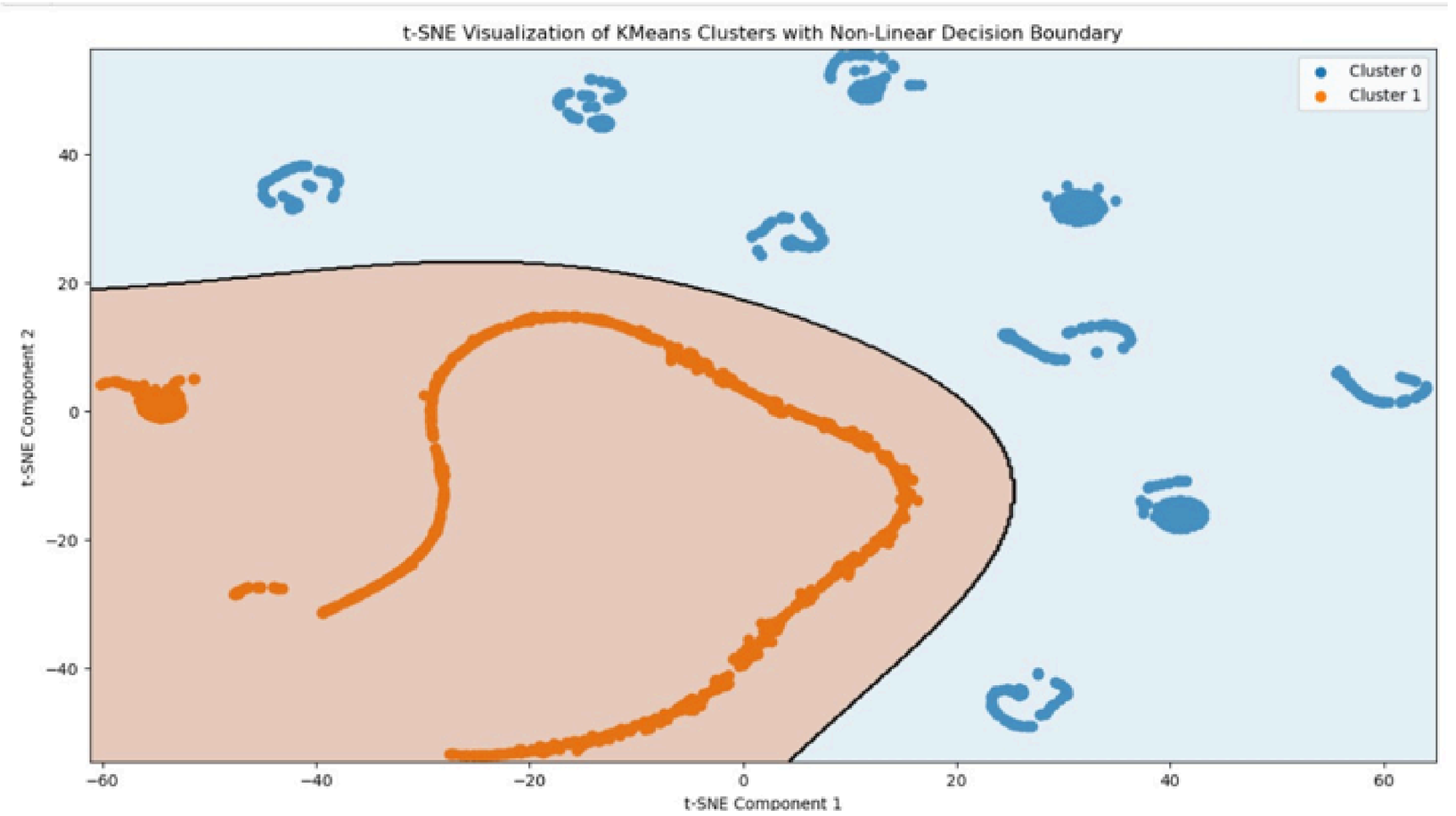


CLUSTERING OF FEATURES

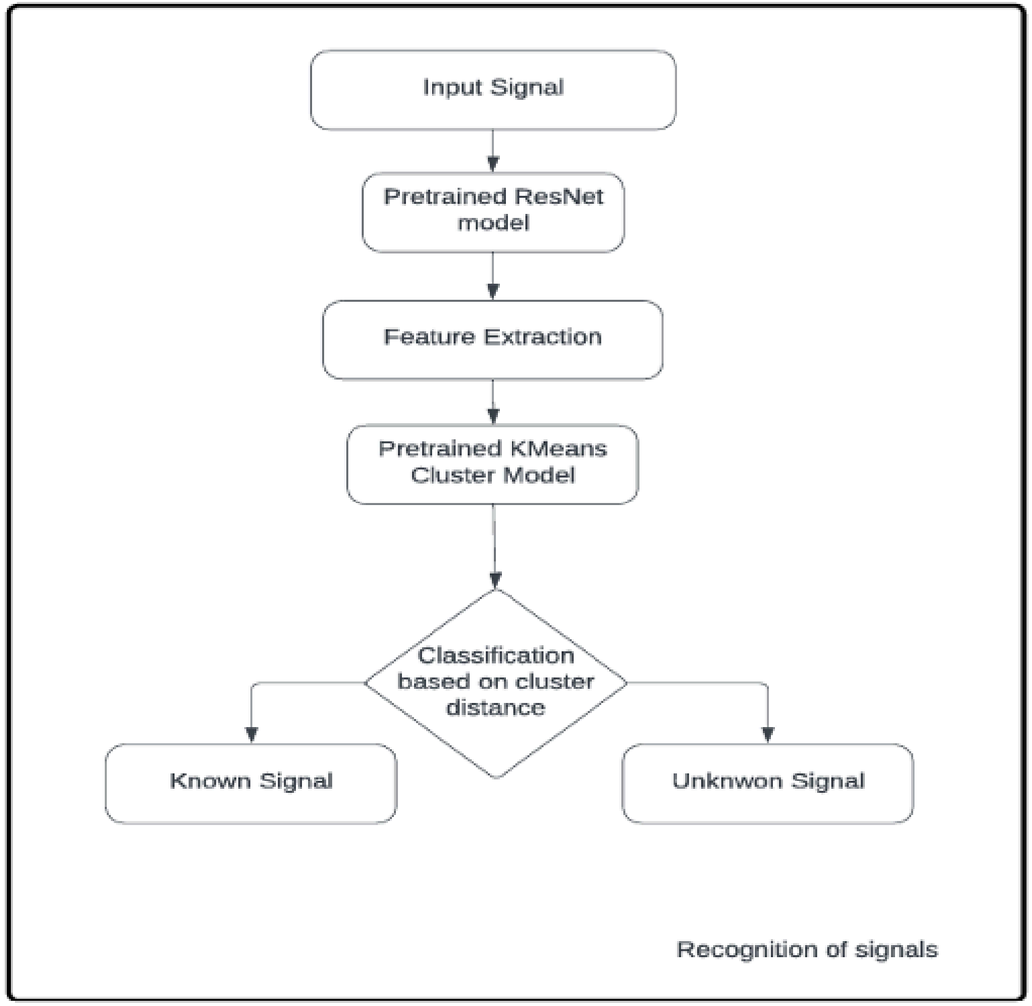


Clustering of features

t-SNE Visualization of KMeans Clusters with Non-Linear Decision Boundary



RECOGNITION OF SIGNALS



Recognition of signals

Untrained ResNet Model Classification

Label	Correctly Classified	wrongly classified
Known	176	824
Unknown	1000	0

Here the features are extracted from an untrained ResNet model, so it couldn't recognize the known signals accurately.

Model Trained with 20 Classes

Label	Correctly Classified	wrongly classified
Known	889	111
Unknown	708	292

Here, the model could recognize both signals with better accuracy, but it couldn't recognize unknown signals with 100% accuracy.

Model Trained with 10 Classes

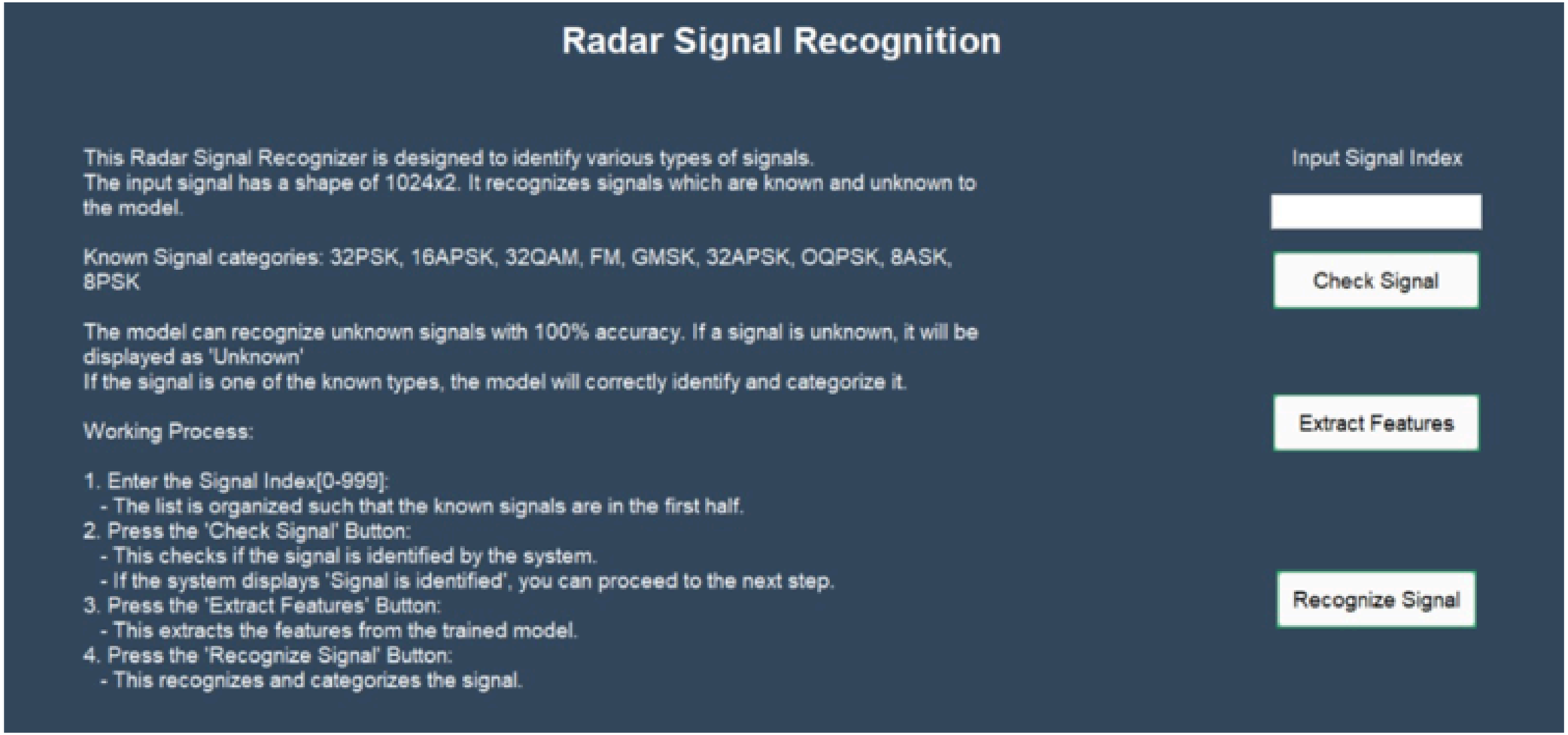
Label	Correctly Classified	wrongly classified
Known	889	111
Unknown	1000	0

Here, unknown signals where recognized with 100% accuracy and known signals where recognized with 89% accuracy.

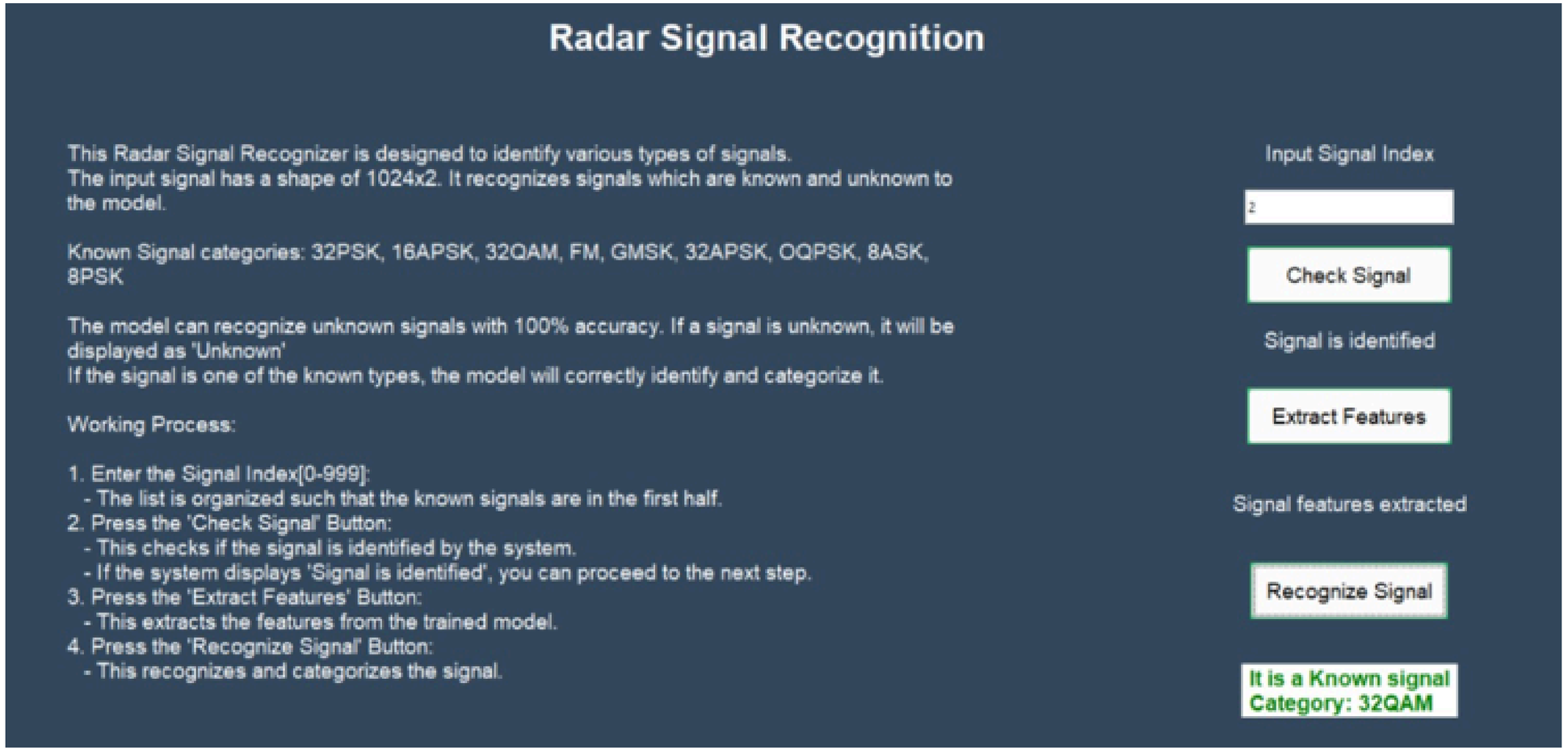
Classification for 40,000 samples

Label	Correctly Classified	wrongly classified
Known	18036	1964
Unknown	20000	0

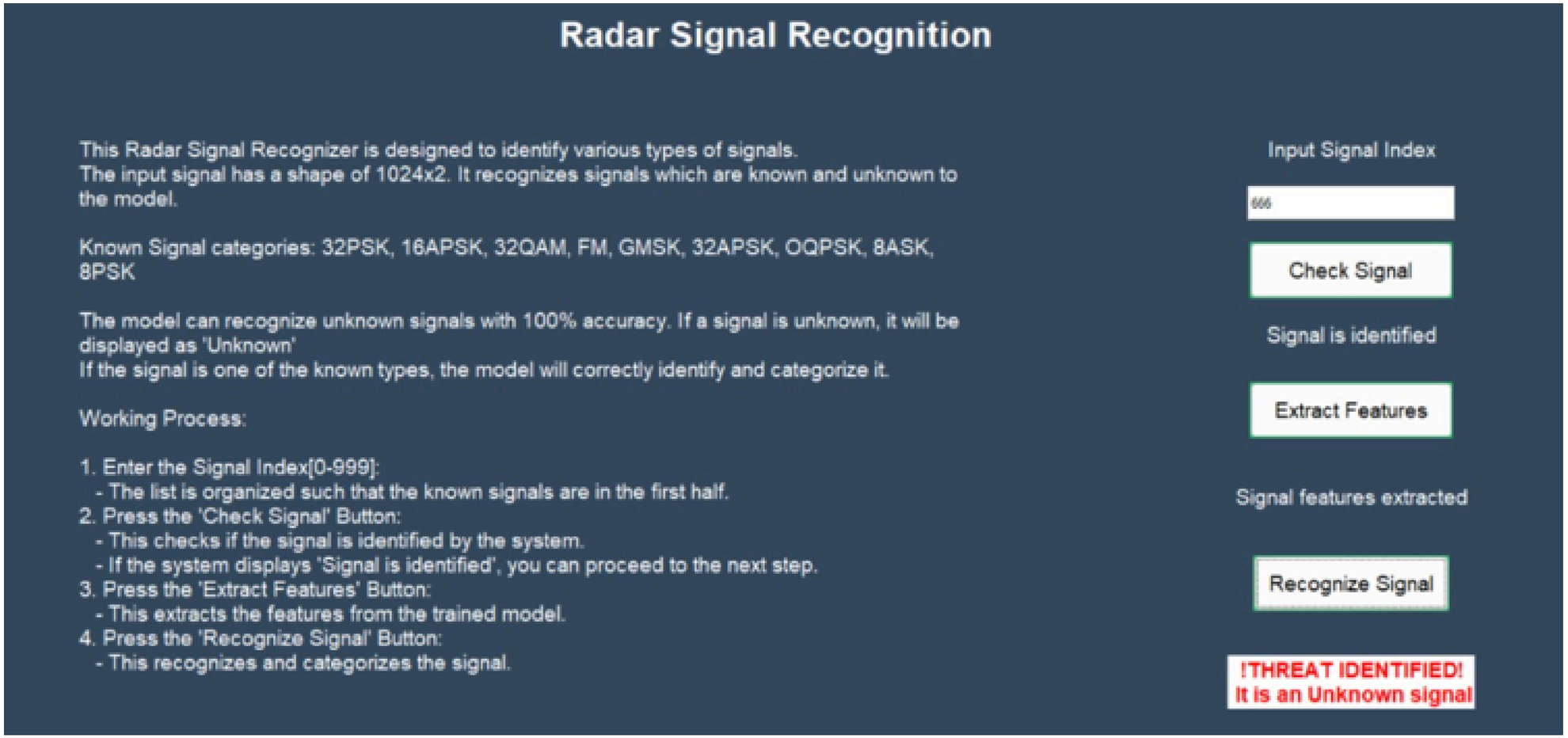
Interface


Radar Signal Recognition
This Radar Signal Recognizer is designed to identify various types of signals.
The input signal has a shape of 1024x2. It recognizes signals which are known and unknown to the model.
Known Signal categories: 32PSK, 16APSK, 32QAM, FM, GMSK, 32APSK, OQPSK, 8ASK, 8PSK
The model can recognize unknown signals with 100% accuracy. If a signal is unknown, it will be displayed as 'Unknown'
If the signal is one of the known types, the model will correctly identify and categorize it.
Working Process:
1. Enter the Signal Index[0-999]:
- The list is organized such that the known signals are in the first half.
2. Press the 'Check Signal' Button:
- This checks if the signal is identified by the system.
- If the system displays 'Signal is identified', you can proceed to the next step.
3. Press the 'Extract Features' Button:
- This extracts the features from the trained model.
4. Press the 'Recognize Signal' Button:
- This recognizes and categorizes the signal.
Input Signal Index
Check Signal
Extract Features
Recognize Signal

Interface


Radar Signal Recognition
This Radar Signal Recognizer is designed to identify various types of signals.
The input signal has a shape of 1024x2. It recognizes signals which are known and unknown to the model.
Known Signal categories: 32PSK, 16APSK, 32QAM, FM, GMSK, 32APSK, OQPSK, 8ASK, 8PSK
The model can recognize unknown signals with 100% accuracy. If a signal is unknown, it will be displayed as 'Unknown'
If the signal is one of the known types, the model will correctly identify and categorize it.
Working Process:
1. Enter the Signal Index[0-999]:
- The list is organized such that the known signals are in the first half.
2. Press the 'Check Signal' Button:
- This checks if the signal is identified by the system.
- If the system displays 'Signal is identified', you can proceed to the next step.
3. Press the 'Extract Features' Button:
- This extracts the features from the trained model.
4. Press the 'Recognize Signal' Button:
- This recognizes and categorizes the signal.
Input Signal Index
2
Check Signal
Signal is identified
Extract Features
Signal features extracted
Recognize Signal
It is a Known signal
Category: 32QAM

Interface


Radar Signal Recognition
This Radar Signal Recognizer is designed to identify various types of signals.
The input signal has a shape of 1024x2. It recognizes signals which are known and unknown to the model.
Known Signal categories: 32PSK, 16APSK, 32QAM, FM, GMSK, 32APSK, OQPSK, 8ASK, 8PSK
The model can recognize unknown signals with 100% accuracy. If a signal is unknown, it will be displayed as 'Unknown'
If the signal is one of the known types, the model will correctly identify and categorize it.
Working Process:
1. Enter the Signal Index[0-999]:
- The list is organized such that the known signals are in the first half.
2. Press the 'Check Signal' Button:
- This checks if the signal is identified by the system.
- If the system displays 'Signal is identified', you can proceed to the next step.
3. Press the 'Extract Features' Button:
- This extracts the features from the trained model.
4. Press the 'Recognize Signal' Button:
- This recognizes and categorizes the signal.
Input Signal Index
666
Check Signal
Signal is identified
Extract Features
Signal features extracted
Recognize Signal
!THREAT IDENTIFIED!
It is an Unknown signal

CONCLUSION

- In this project, we developed an advanced machine learning framework for recognizing unknown radar emitters using Residual Neural Networks (ResNet).
- Rigorous testing showed our model's effectiveness, with notable accuracy rates: 91.9% for known samples and 100% for unknown samples when trained with 10 classes.


Thank
You