CAPSTONE - II

# Development of AI Tool for the Detection of Mines using GPR

# Group Members -

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# Project Guide -

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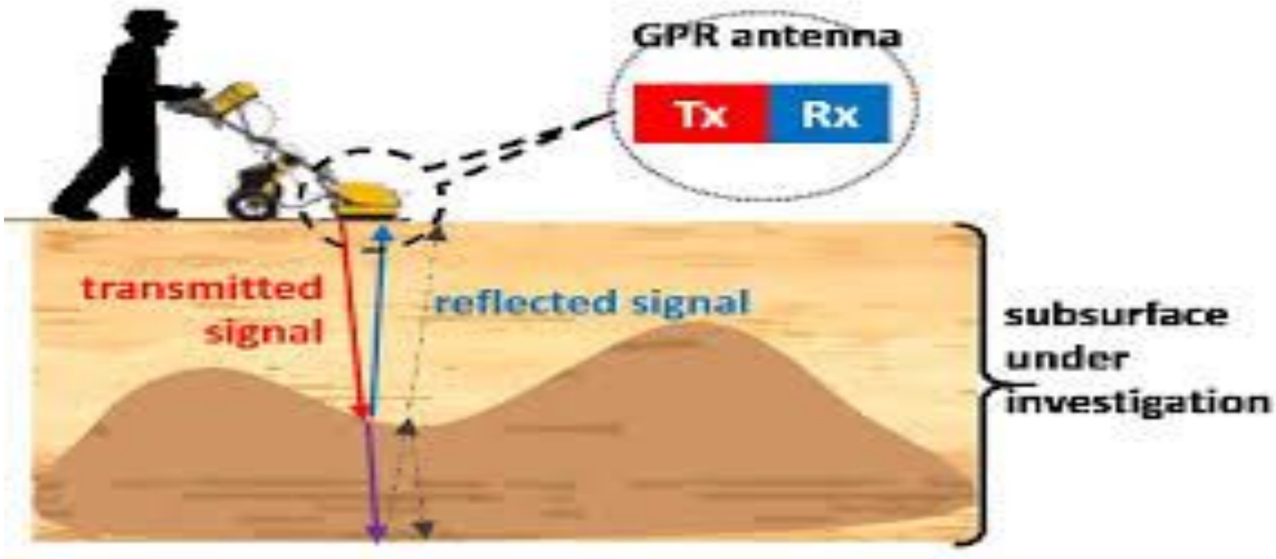
# GPR and Its Working

- GPR stands for Ground Penetrating Radar. It uses EM waves for detection of within various surfaces.
- The main components of GPR include: Transmitter, Receiver and Control Unit.



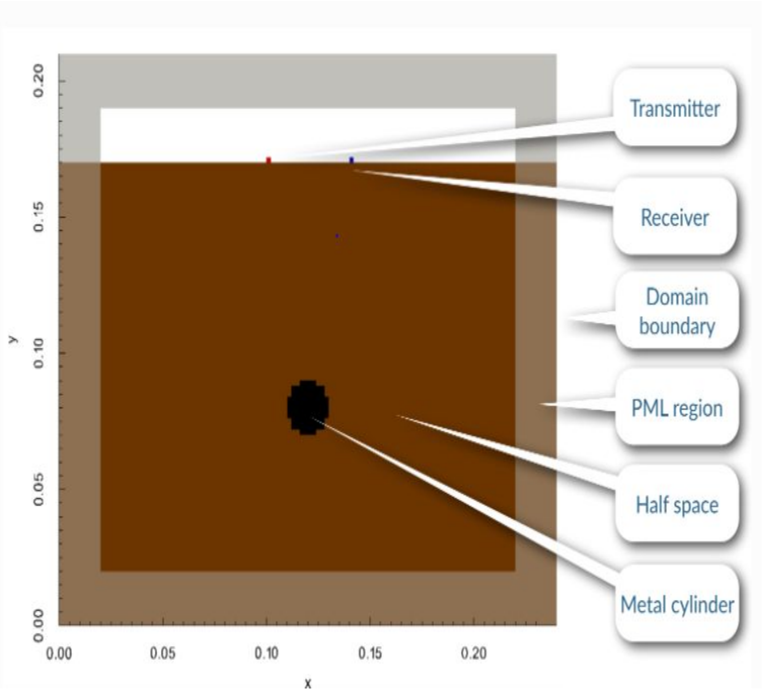
# gprMax

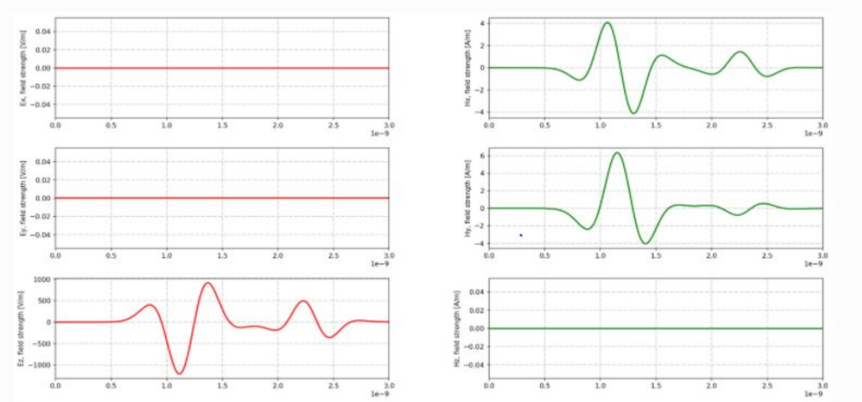
- gprMax is open-source software that simulates electromagnetic wave propagation.
- It solves Maxwell’s equations in 3D using the Finite-Difference Time-Domain (FDTD) method.
- It  is command-line-driven software.
- It produces A-scan and B-scan plots as output.

```
#title: Water Puddles
#domain: 1.0 0.25 0.45
#dx_dy_dz: 0.001 0.001 0.001
#time_window: 6e-9

#python:
from user_libs.antennas.GSSI import antenna_like_GSSI_1500
antenna_like_GSSI_1500(0.1 + current_model_run * 0.006, 0.126,0.24,0.001)
#end_python:

#soil_peplinski: 0.5 0.5 2.0 2.66 0.001 0.25 my_soil
#fractal_box: 0 0 0 1.0 0.25 0.2 1.5 1 1 1 50 my_soil my_soil_box
#add_surface_roughness: 0 0 0.2 1.0 0.25 0.2 1.5 1 1 0.195 0.205 my_soil_box
#add_surface_water: 0 0 0.2 1.0 0.25 0.2 0.203 my_soil_box

#material: 3.5 0.01 1.0 0 bakelite
#material: 6.0 0.01 1.0 0 rubber
#material: 2.86 0.00048 1.0 9.75 TNT
#material: 2.4 0 1 0 plastic

        PMN
#cylinder: 0.3 0.126 0.15 0.3 0.126 0.147 0.056 rubber
#cylinder: 0.3 0.126 0.147 0.3 0.126 0.094 0.056 bakelite
#cylinder: 0.3 0.126 0.147 0.3 0.126 0.097 0.053 TNT
#cylinder: 0.3 0.126 0.147 0.3 0.126 0.097 0.002 pec

        PMA-1
#box: 0.65 0.09 0.12 0.79 0.16 0.15 plastic
#box: 0.67 0.10 0.13 0.77 0.15 0.14 TNT
#cylinder: 0.67 0.12 0.135 0.77 0.12 0.135 0.002 pec
```

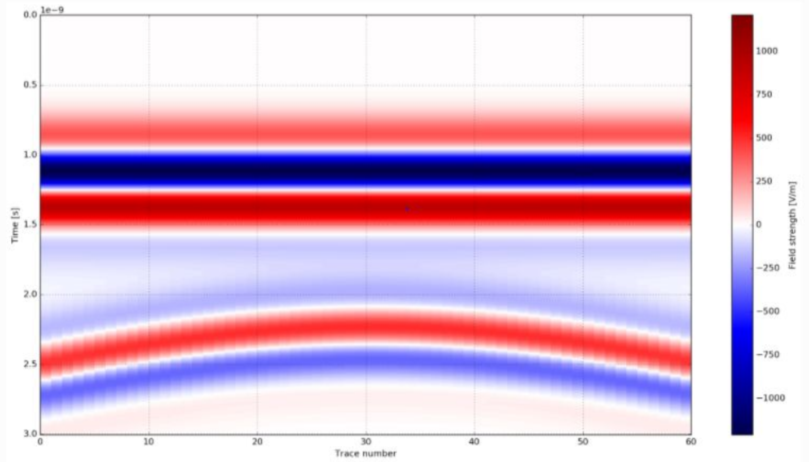
Input File

# A-scan and B-scan

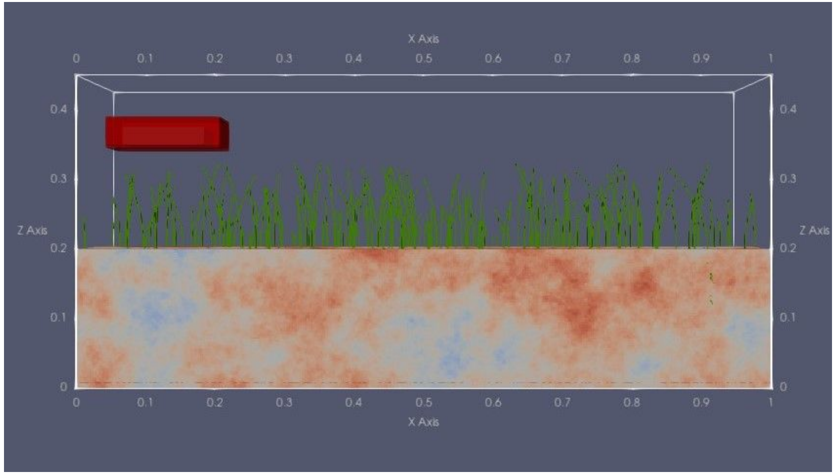


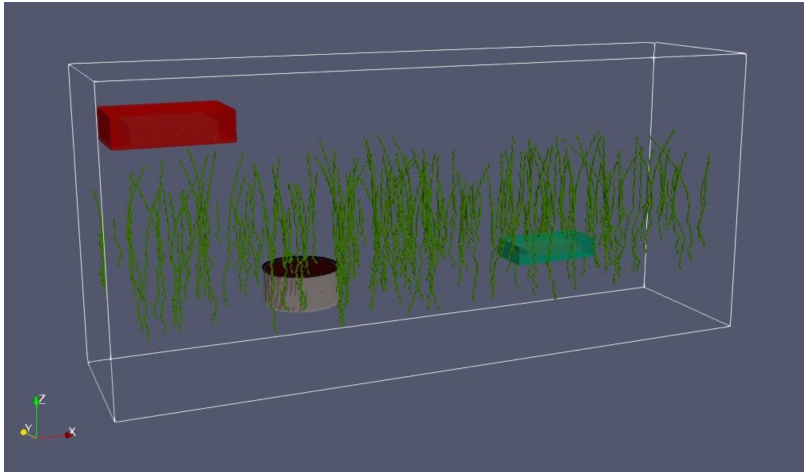



A-scan

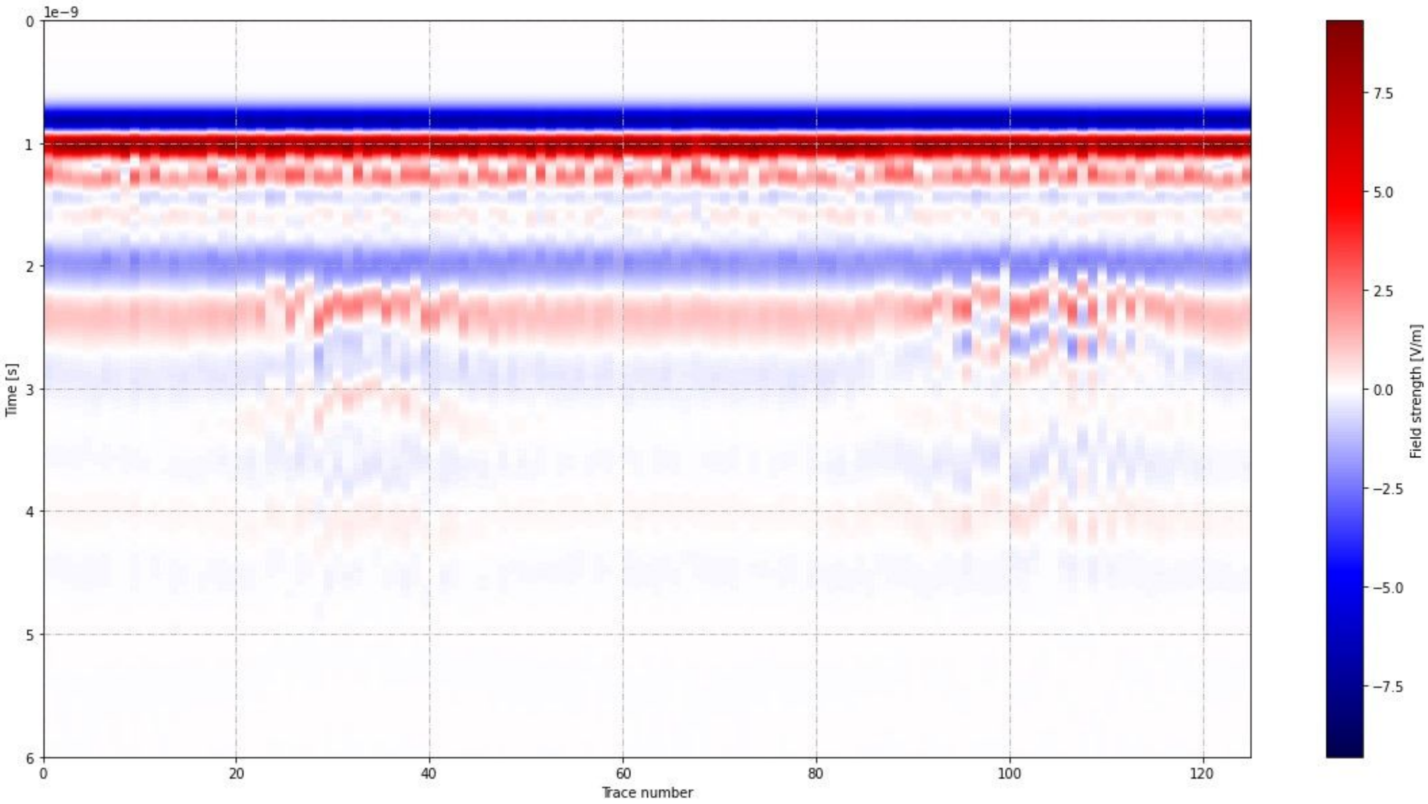



B-scan





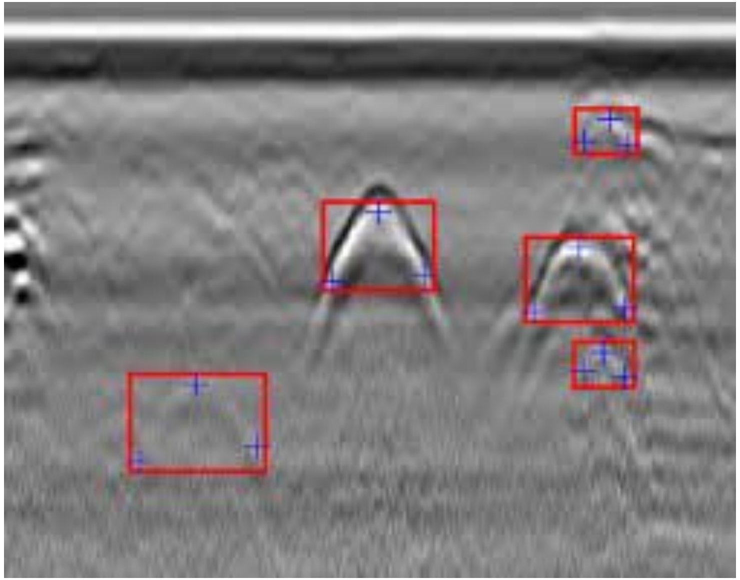

Simulation Model Visualization using ParaView Software




B-scan result

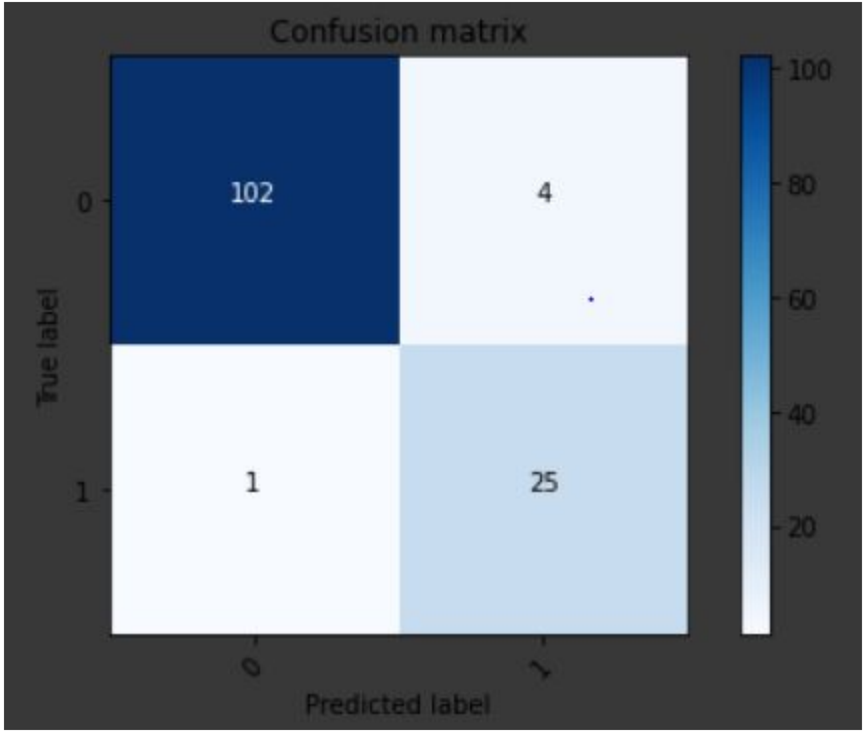
# Previous Model's Working

- Landmines are detected using GPR.
- GPR provides us with a B scan- which is a 2d image of the subsurface.
- To generate the data we used gprMax software.
- We trained  a Convolutional Neural Network(CNN) on the B-scan to detect hyperbolas.
- This hyperbola denotes the presence and absence of mines.

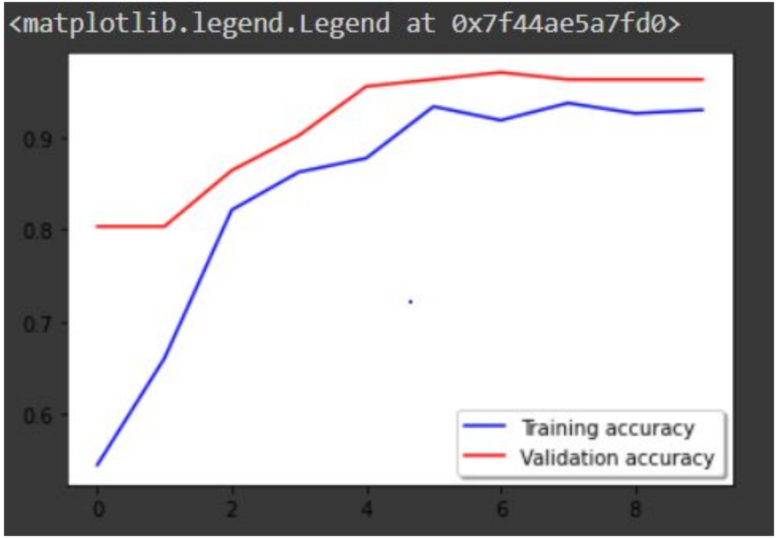


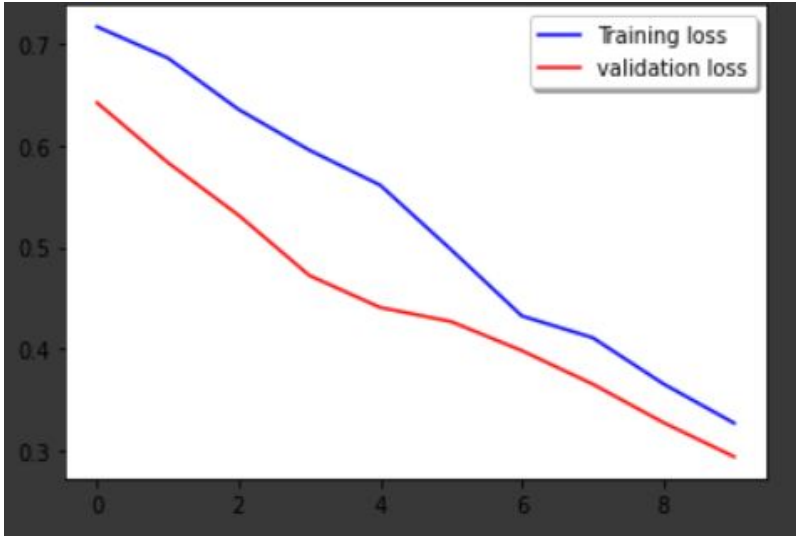
# Previous Results

- ❖ Confusion Matrix on Test data
- ❖ Accuracy: 96.21%



# Accuracy And Loss vs No. of epochs

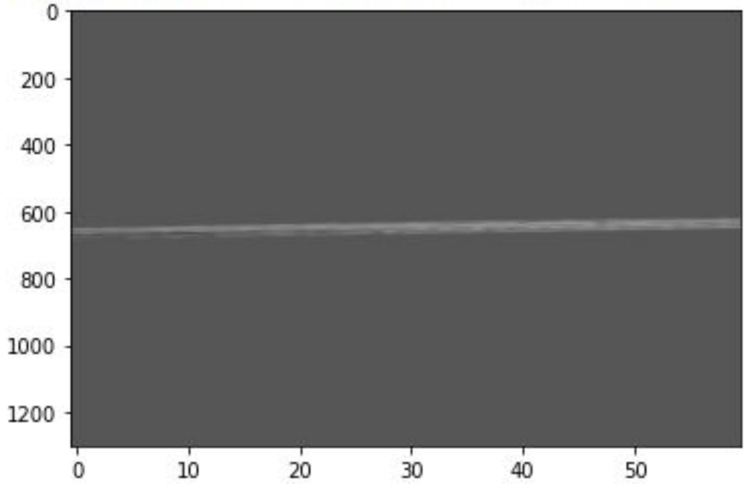


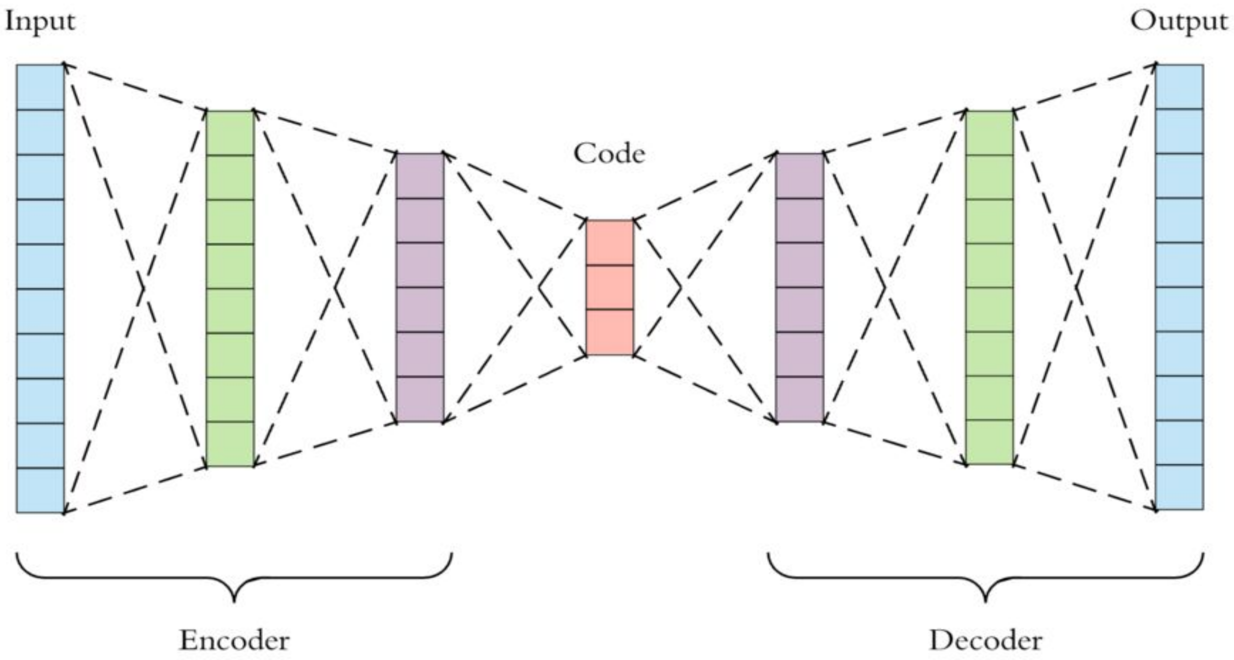
# Drawbacks of the previous model

- **<u>Identifying rock with similar hyperbola as a mine (false positive)</u>**
- Abnormal results when using data augmentation techniques to improve training data
- Confidence score not good (around 50%)
- Position change affect the results

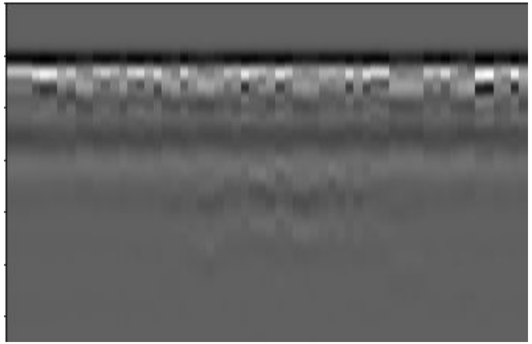
```
[[0.45771116 0.5422888 ]]
[[0.83512586 0.16487415]]
[[0.44958815 0.5504119 ]]
[[0.45326602 0.546734  ]]
<matplotlib.image.AxesImage at 0x7f6f9f944e10>
```



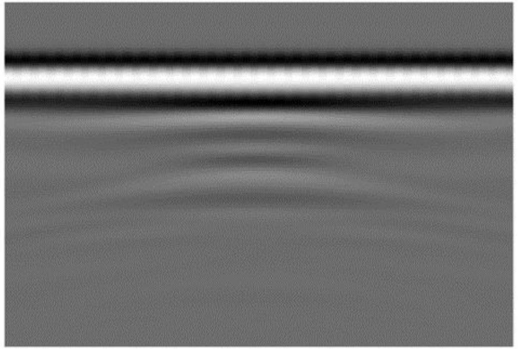
# Autoencoders



# Denoising Autoencoder



Input



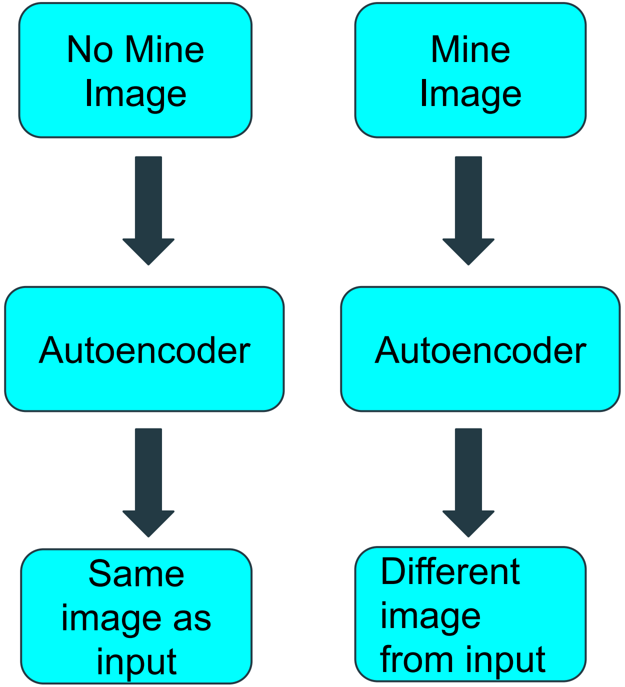
Output

# Anomaly Detection

- Identifying unexpected items or events in data sets, which differ from the norm
- To detect outliers

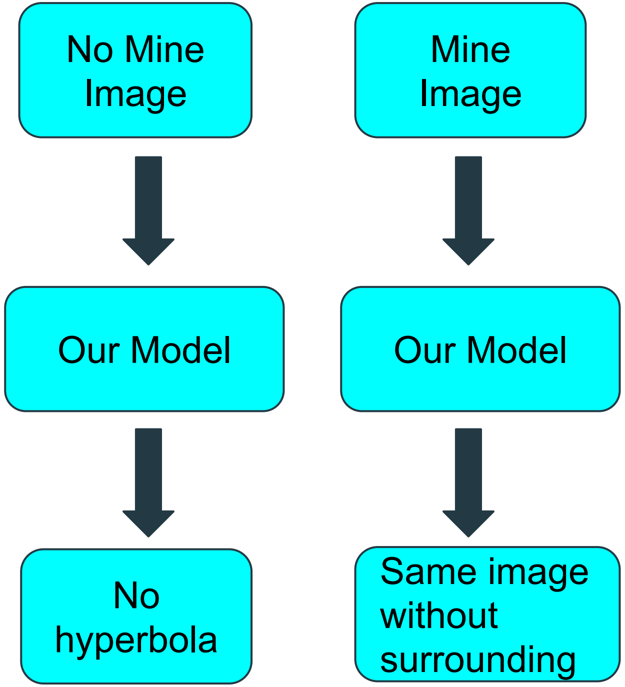
# Existing Work with Autoencoders

- Autoencoders are trained on without mine data
- Mine is treated as an anomaly
- There are chances of false detection of clutter as mine
- Huge amount of training data is required to cover the various kinds of surfaces



# Novelty in Our Approach

- Autoencoders are trained on mine data
- Surroundings is treated as an anomaly
- Gives better results
- Less amount of training data is required.



# Model Architecture

- Input Size:1300*60
- Encoder Layer : 32 nodes, Relu activation
- Decoder Layer : 1300*60, Sigmoid activation
- Loss Function = Binary cross entropy
- Optimizer = Adam

# Dataset for Training the Model

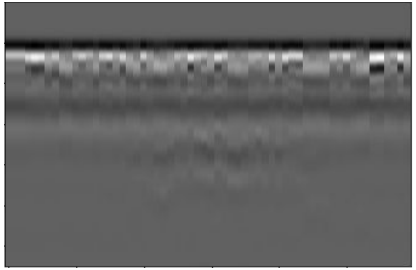
- Consists of 200 B-scan images which include mines
- Varied soil properties, vegetation, moisture content and surface roughness
- Depth of the mines from is also varied in some cases

| Clay Fraction (Mean = 0.6) | Bulk Density (g/cc) (Mean = 2) | Sandparticle Density (g/cc) (Mean = 2.66) | Water Fraction (Range: 0.05-0.25) | Surface Roughness (lower limit)(Mean = 0.25) | Surface Roughness (higher limit) | Height of Vegetation (lower Limit) | Height of Vegetation (higher limit) | Depth of Mine (w.r.t surface at 0.25) |
|---|---|---|---|---|---|---|---|---|
| 0.631 | 1.988 | 2.727 | 0.199 | 0.231 | 0.271 | 0.263 | 0.291 | 0.159 |
| 0.569 | 1.94 | 2.924 | 0.099 | 0.234 | 0.256 | 0.267 | 0.297 | 0.19 |
| 0.491 | 1.881 | 2.796 | 0.106 | 0.244 | 0.285 | 0.259 | 0.293 | 0.146 |
| 0.577 | 1.953 | 2.848 | 0.09 | 0.226 | 0.254 | 0.269 | 0.293 | 0.135 |
| 0.599 | 1.879 | 2.664 | 0.099 | 0.22 | 0.293 | 0.251 | 0.296 | 0.104 |
| 0.483 | 2.209 | 2.643 | 0.065 | 0.235 | 0.274 | 0.268 | 0.295 | 0.109 |
| 0.601 | 2.122 | 2.821 | 0.153 | 0.248 | 0.273 | 0.264 | 0.299 | 0.154 |
| 0.622 | 2.065 | 2.523 | 0.146 | 0.2 | 0.265 | 0.263 | 0.292 | 0.123 |
| 0.591 | 1.998 | 2.653 | 0.06 | 0.204 | 0.295 | 0.252 | 0.293 | 0.184 |
| 0.598 | 2.114 | 2.775 | 0.246 | 0.214 | 0.27 | 0.252 | 0.294 | 0.197 |
| 0.587 | 2.027 | 2.482 | 0.062 | 0.221 | 0.286 | 0.264 | 0.295 | 0.169 |
| 0.562 | 2.156 | 2.657 | 0.11 | 0.219 | 0.278 | 0.258 | 0.292 | 0.172 |
| 0.6 | 2.166 | 2.421 | 0.224 | 0.242 | 0.3 | 0.257 | 0.297 | 0.121 |
| 0.629 | 1.975 | 2.687 | 0.136 | 0.215 | 0.255 | 0.254 | 0.298 | 0.104 |
| 0.613 | 1.953 | 2.724 | 0.089 | 0.203 | 0.279 | 0.258 | 0.291 | 0.114 |

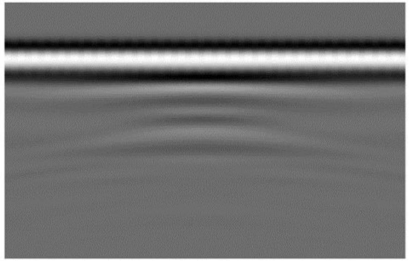
# Dataset for Testing the Model

- Using Validation Set of the previous dataset
- With B-scans of rock and metallic cylinder of same size
- Varying the properties of the buried object from rock to mine using a linear relationship, $P = (1 - \alpha)P(rock) + \alpha P(mine)$
- Increasing the size of the mine like diameter or height by around 10 percent

# Results: Decoded Images

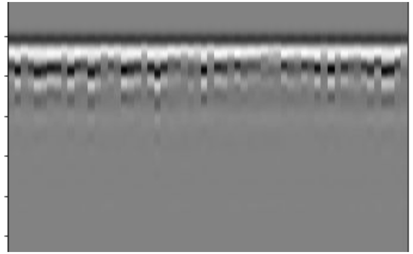


input

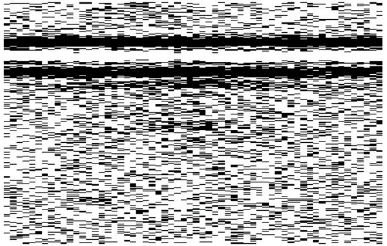


Decoded image

**Mine**

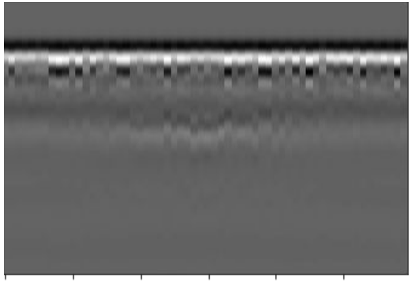


input

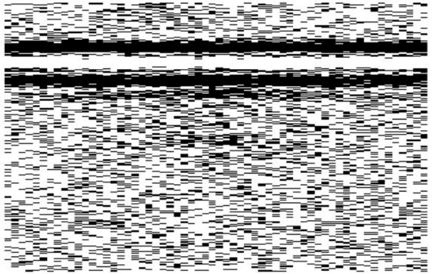


Decoded image

**No mine**

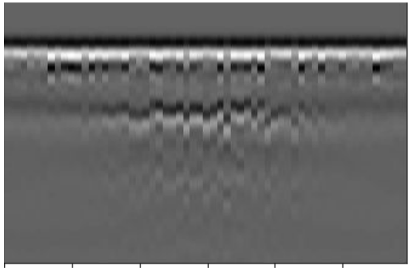


input

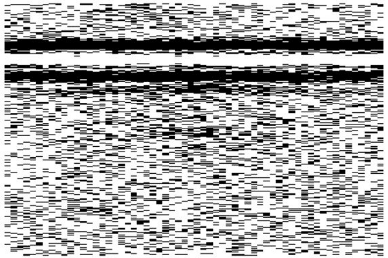


Decoded image

**Rock**



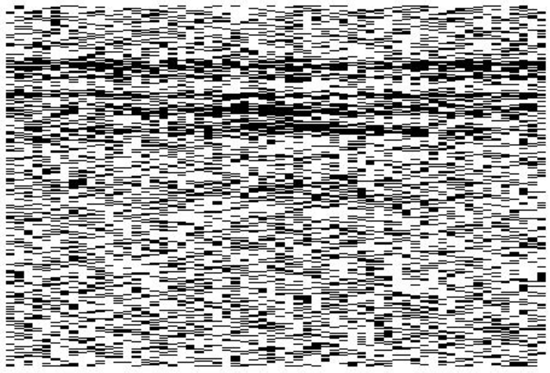
input



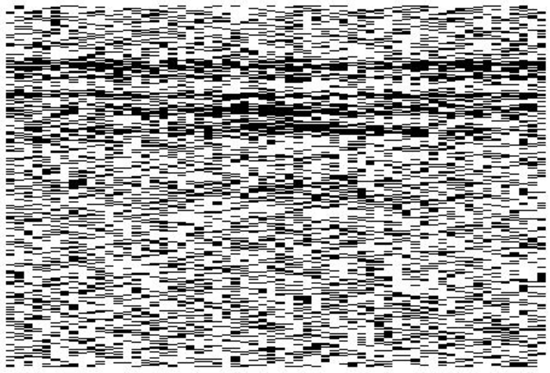
Decoded image

**Metallic Cylinder**

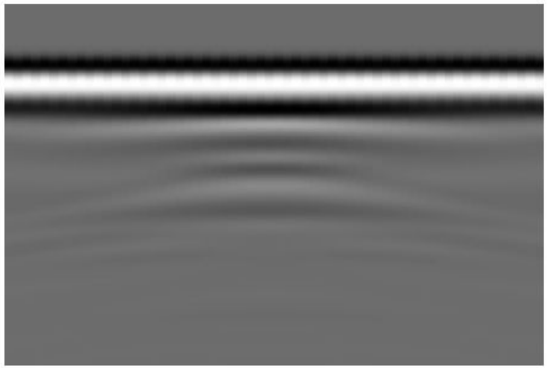
# Linear Variation in Properties



α = 0.4

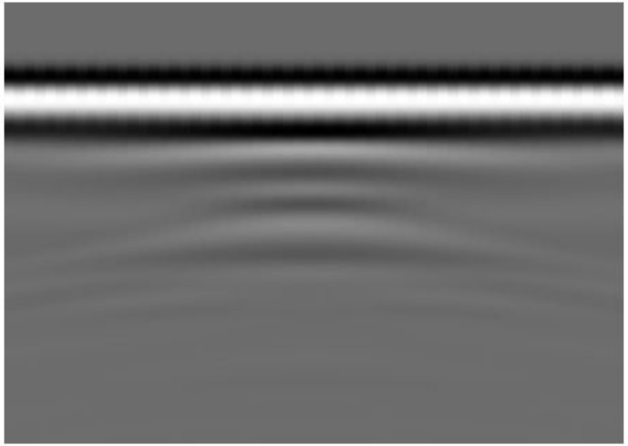


α = 0.8

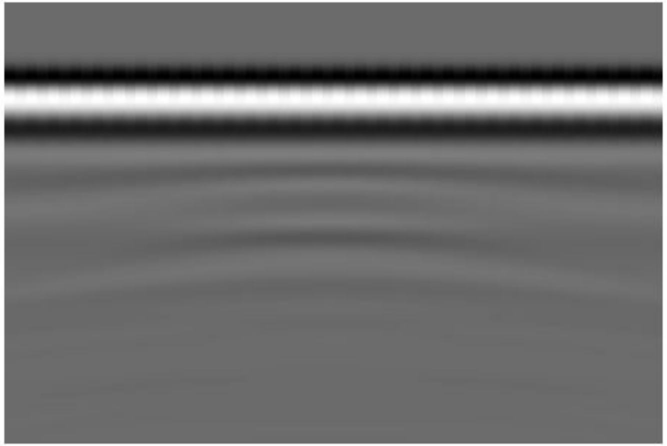


α = 1 (Mine)

# Varying Mine Size



Normal Mine



Mine with 10 % increased diameter

# Conclusion

- An anomaly detection technique based on denoising autoencoders for landmine detection in GPR data is proposed
- Understands the underlying patterns of a mine better than the previous model
- No large diverse training data involving various kinds of soil is required
- Detects the desirable object underground, just need to train the system accordingly
- The system is robust to a wide variety of environmental conditions

# Thank You!!!