Ionospheric Echo Detection Using Convolutional Neural Networks

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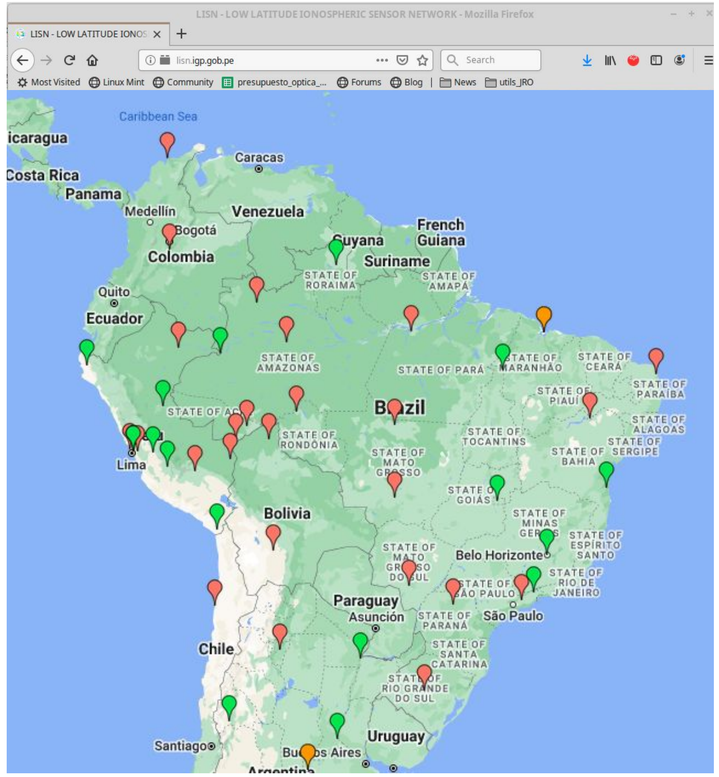
LISN project

LISN is a multi instrument, multi institution, multi project where geophysical observation instruments have been deployed in several South American countries.

Study the electrodynamics of the ionosphere.

Data freely available at www.lisn.igp.gob.pe



LISN instruments

Dataset

LISN has 4 ionosondes in Perú, Argentina and Bolivia. One will be installed in Colombia.

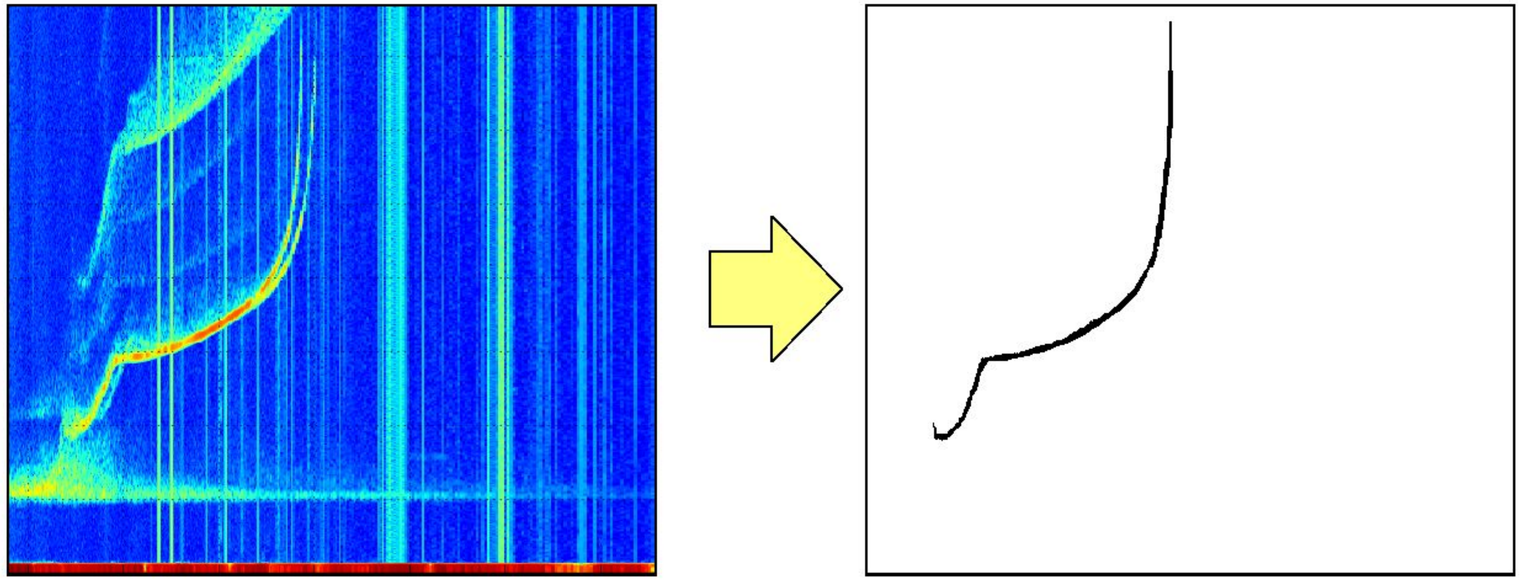
These ionosondes generate a big amount of data -> CNN to detect echoes

- 1,000,000 ionograms in the database.
- 50,780 ionograms used:
- 512 ranges x 408 frequencies
- 817 were selected for labeled data (manual echo extraction)
- https://www.kaggle.com/cdelajara/ionograms

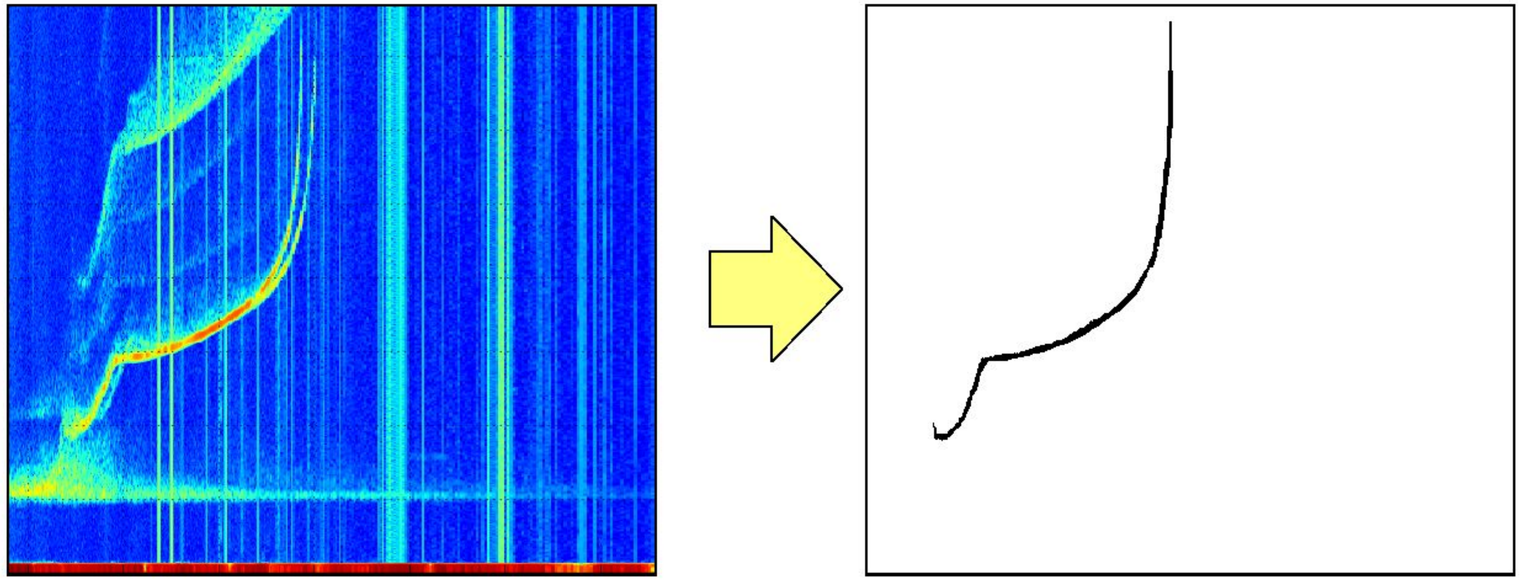
LISN ionosondes

It is not possible to use manual scaling regularly → Deep learning model.

This work is an attempt to develop a system to scale LISN ionograms.



We propose a method to extract ionospheric echoes from digital ionograms using neural networks implementing semantic segmentation, where the goal is to label each pixel as echo or background.

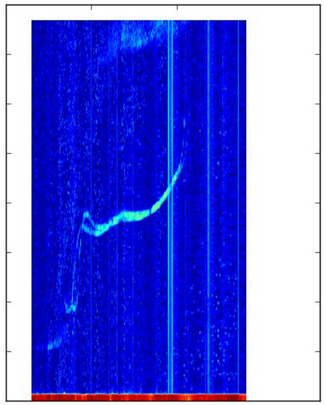


Performance metrics:

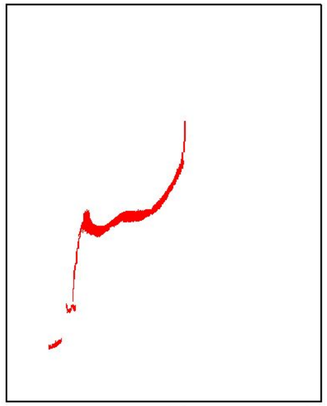
Extract ionospheric layers

Pixel: ionospheric trace or background

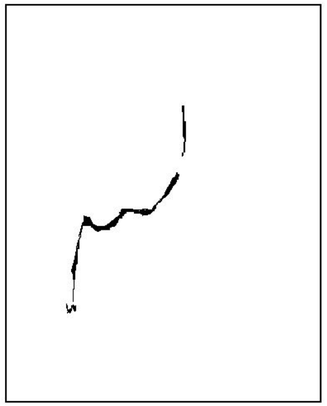
$$\text{IoU} = \frac{\text{common area}}{\text{total area}}$$



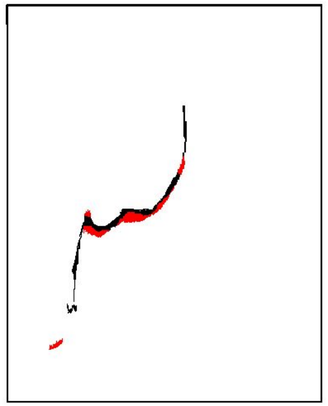
Ionograma Original



Segmentación manual



Segmentación automática



Determinación de la calidad con IoU

1st stage: Baseline models:

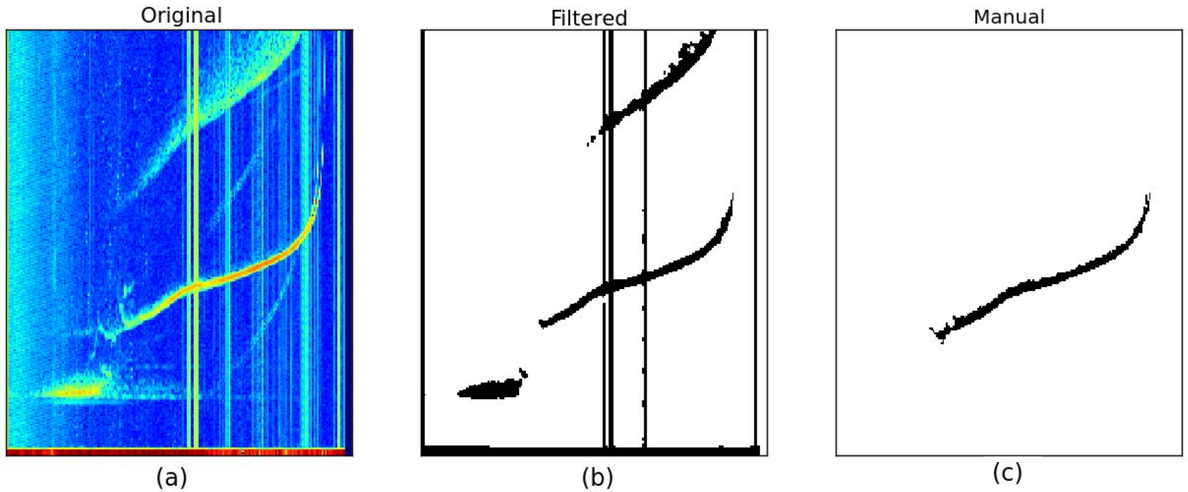
- Filtering and Thresholding
- Unsupervised machine learning models

2nd stage: Neural network models

Filtering and thresholding: Ionograms are considered as images in which the noise should be filtered out to isolate ionospheric echoes:

Median filter + Thresholding

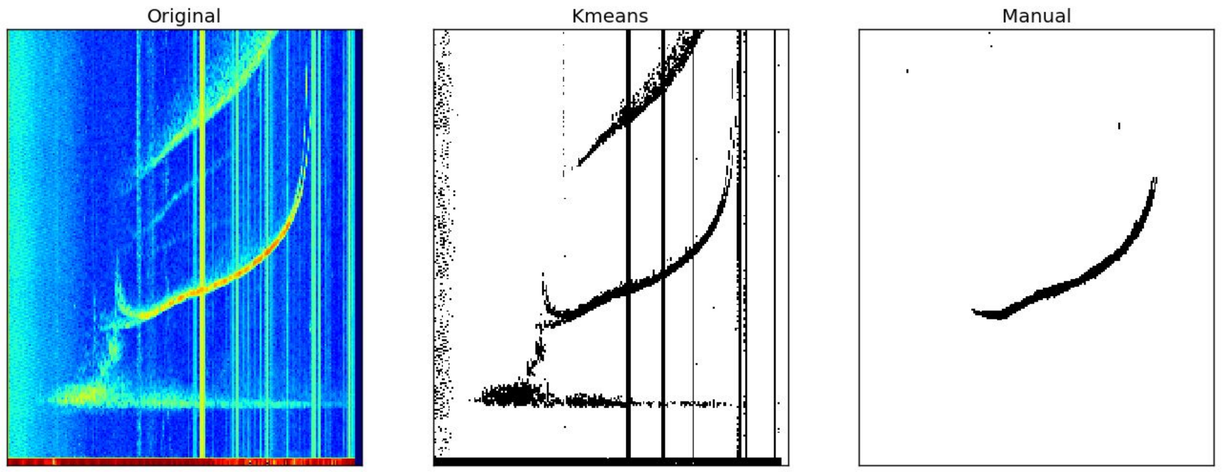
Average IoU: 0.163



Unsupervised machine learning models:

Ionograms are considered three dimensional arrays (x, y, V).

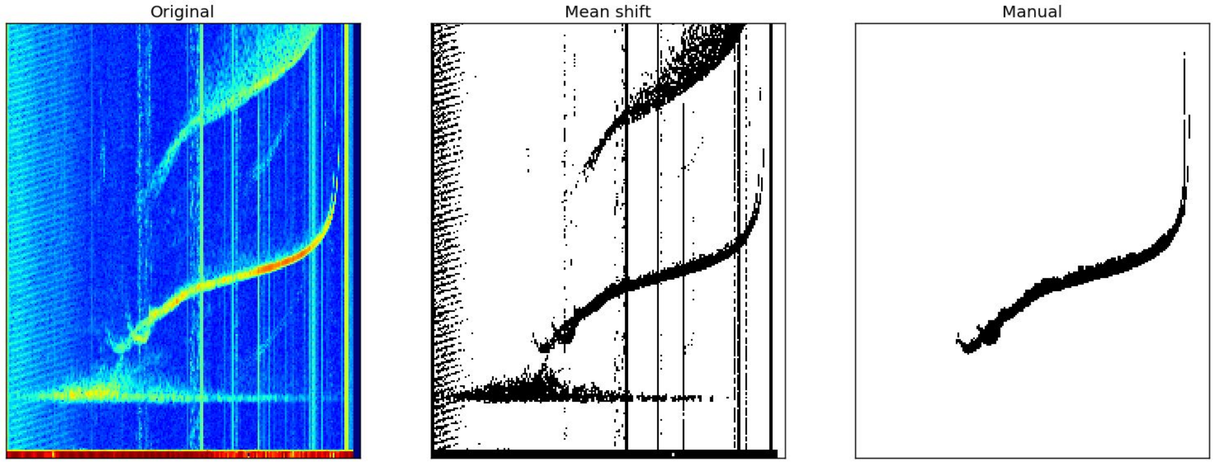
K-Means: K=2. Background and echo



Average IoU: 0.157

Unsupervised machine learning models:

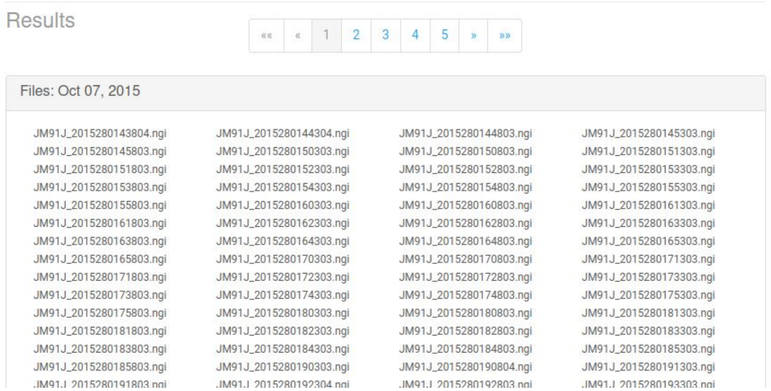
Mean Shift: It doesn't require a previous knowledge of the numbers of clusters



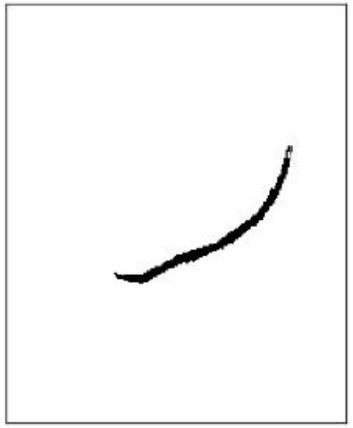
Average IoU: 0.105

Profile detection using CNNs:

LISN database: big amount of unlabeled data



Labeled data: manual segmentation



Semi supervised model:

- Large number of unlabeled data
- Reduced number of labeled data

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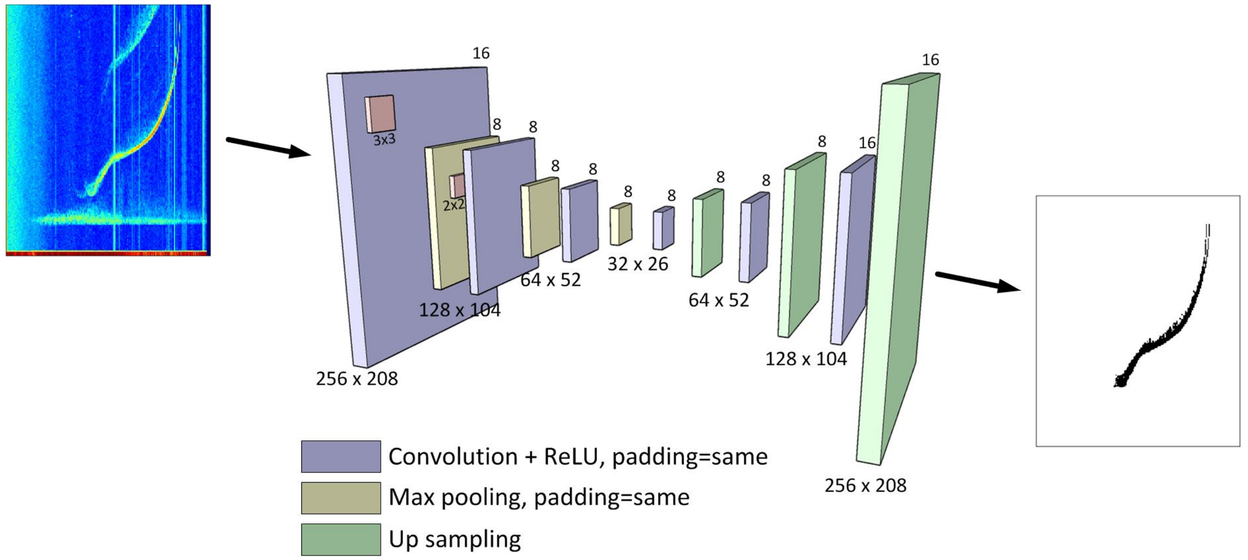
Profile detection using CNNs:

Multilayer convolutional encoder decoder neural network, with multiple layers of convolutions.

The encoder maps the raw inputs to a representations of feature vectors

The decoder processes this features representation to produce an output in the same format than the raw input.

Efficient representation of the data.



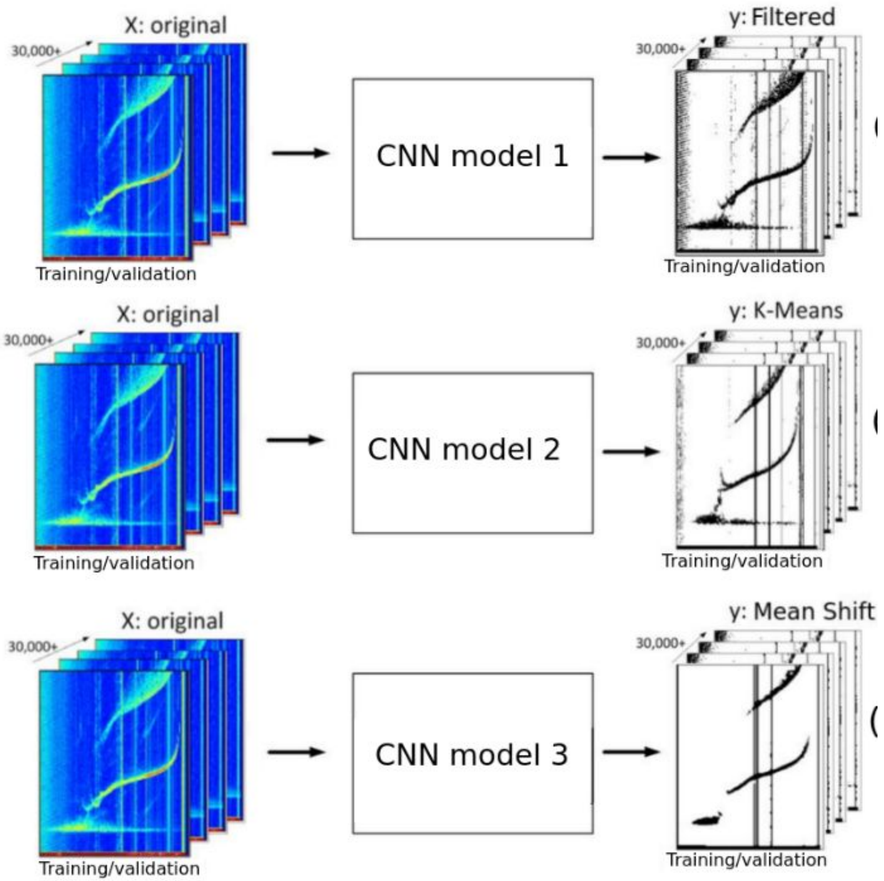
- 6 convolution layers + ReLU
- 3 max pooling, zero padding
- 3 upsampling layers
- Binary cross entropy
- Ada delta

Pre training: Building a neural network model from baseline models

Input: original ionograms.

Output: echoes extracted using baseline models.

3 CNN models are created.



Average IoU:

Filtered: 0.174

K-Means: 0.173

Mean shift: 0.077

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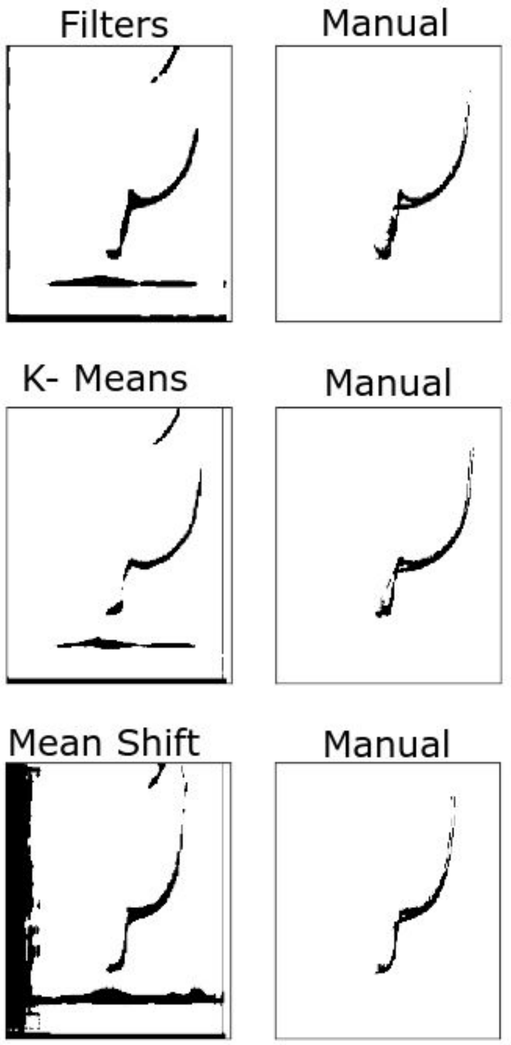


Fine tuning

Input: original ionograms.

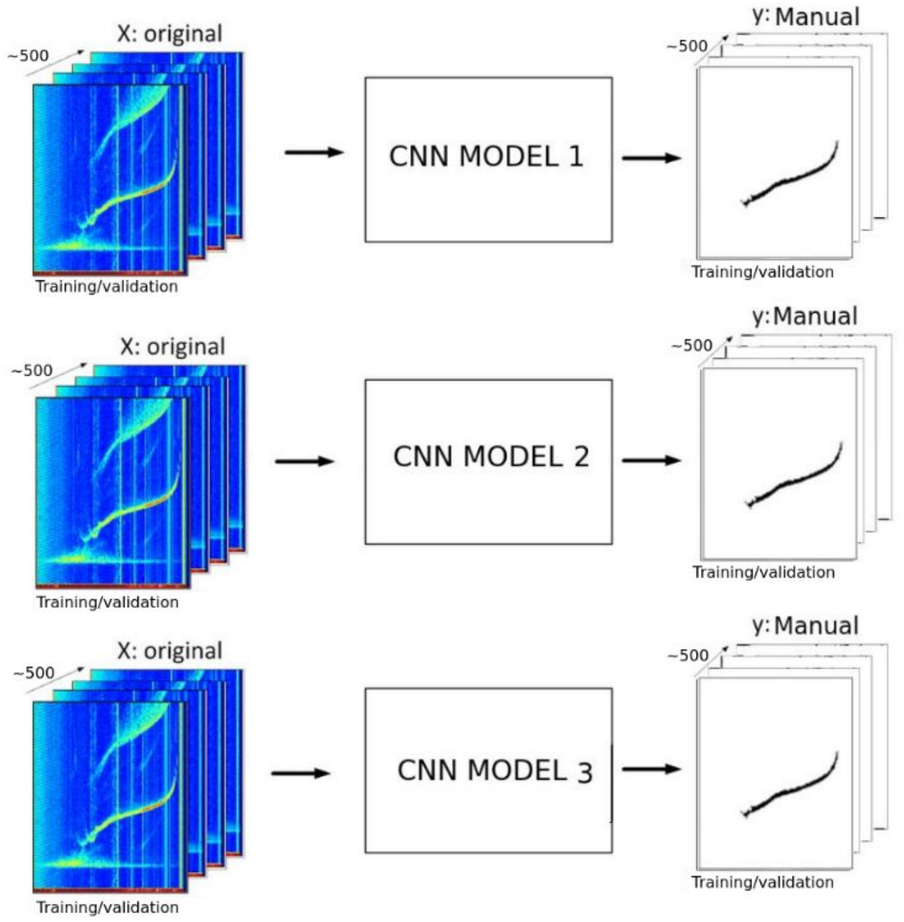
Output: echoes manually extracted.

Average IoU:

Filtered: 0.589

K-Means: 0.602

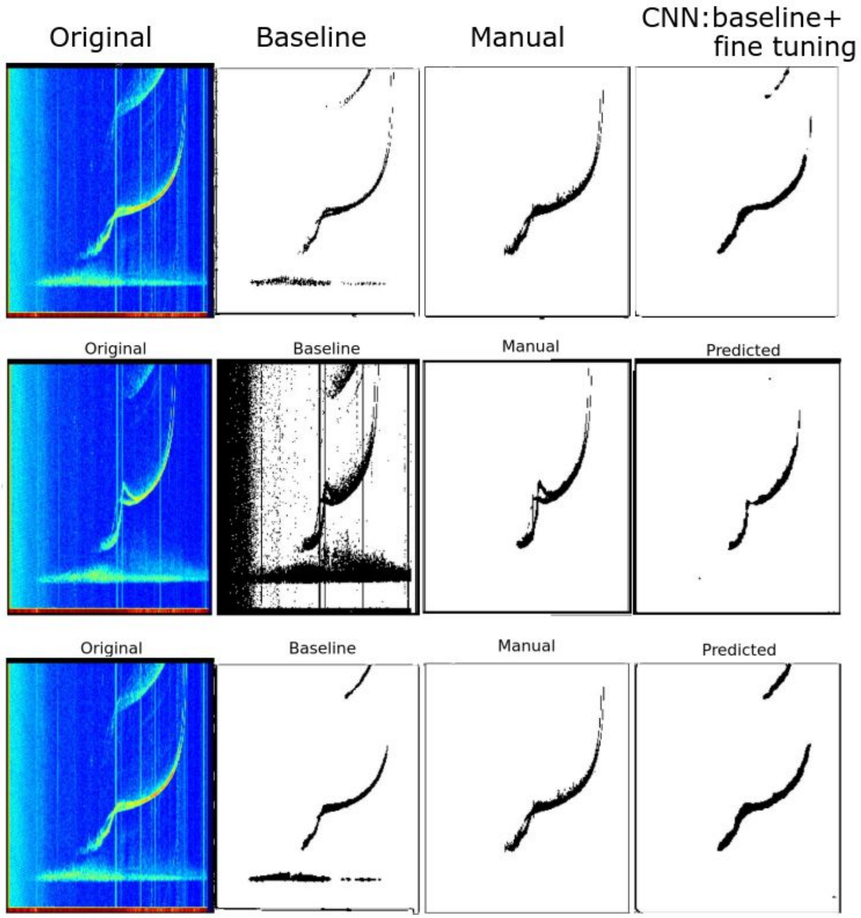
Mean shift: 0.593



Fine tuning and final prediction:
Results of the different stages of the training process

- K-means
- Mean shift
- Filters

A final model was created using only manually extracted data.
Average IoU of 0.569.



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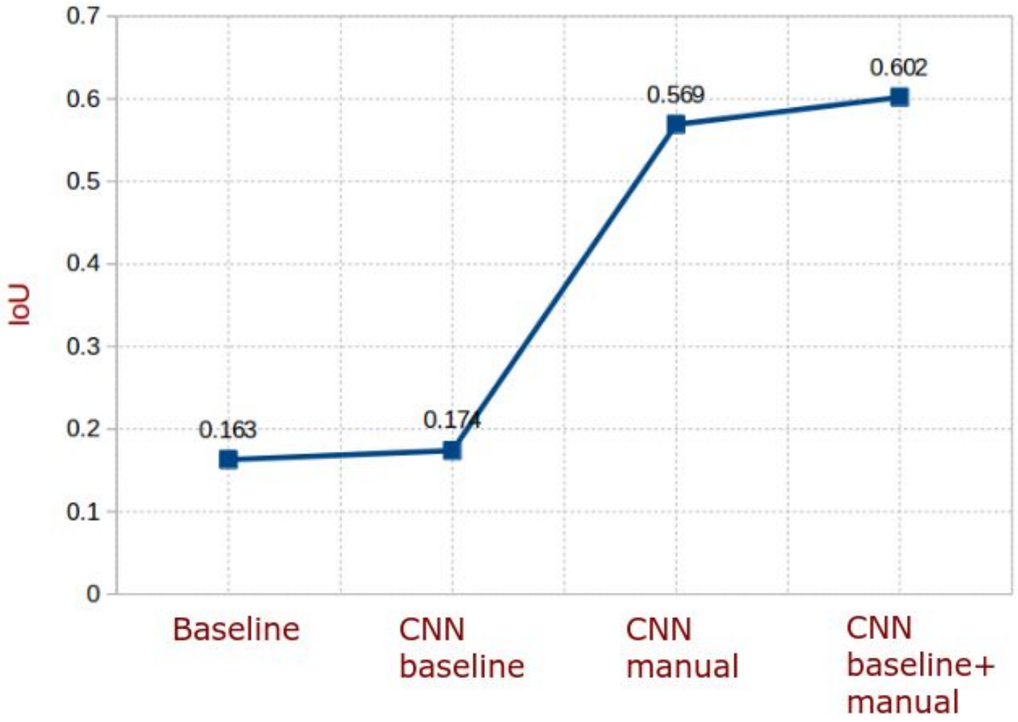

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