ML4NR

Machine learning for noise reduction in old audio records

Bachelor thesis

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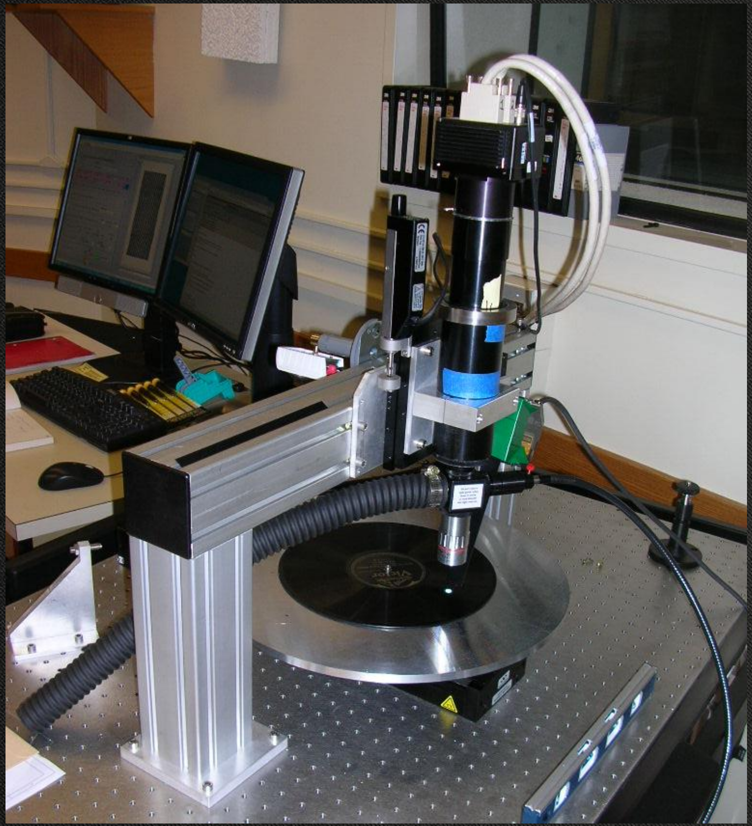
Lawrence Berkeley National Laboratory

Audio records

- Thomas Edison, 1877
- Impractical cylinders
- Brittle material, deterioration
- Here : 78 RPM Shellac discs

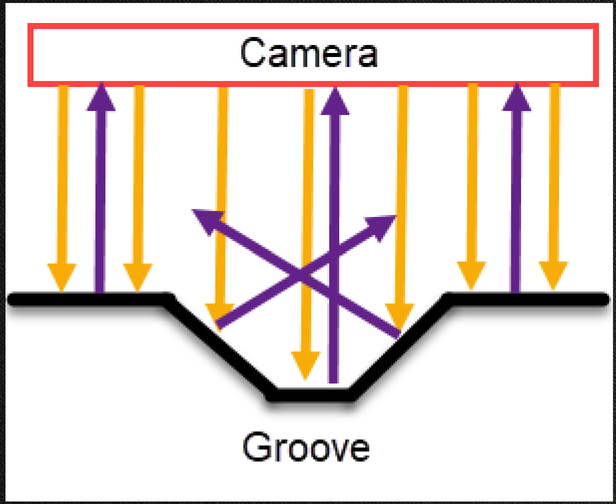
- Preservation of valuable data

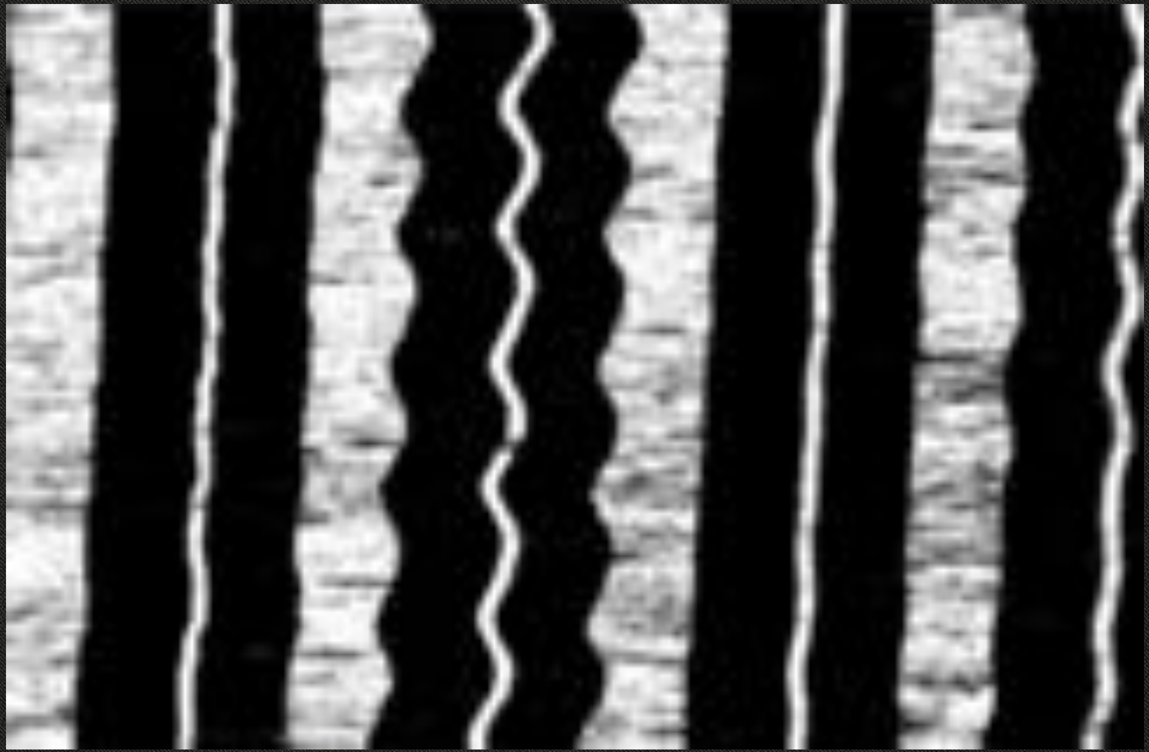
IRENE and Weaver

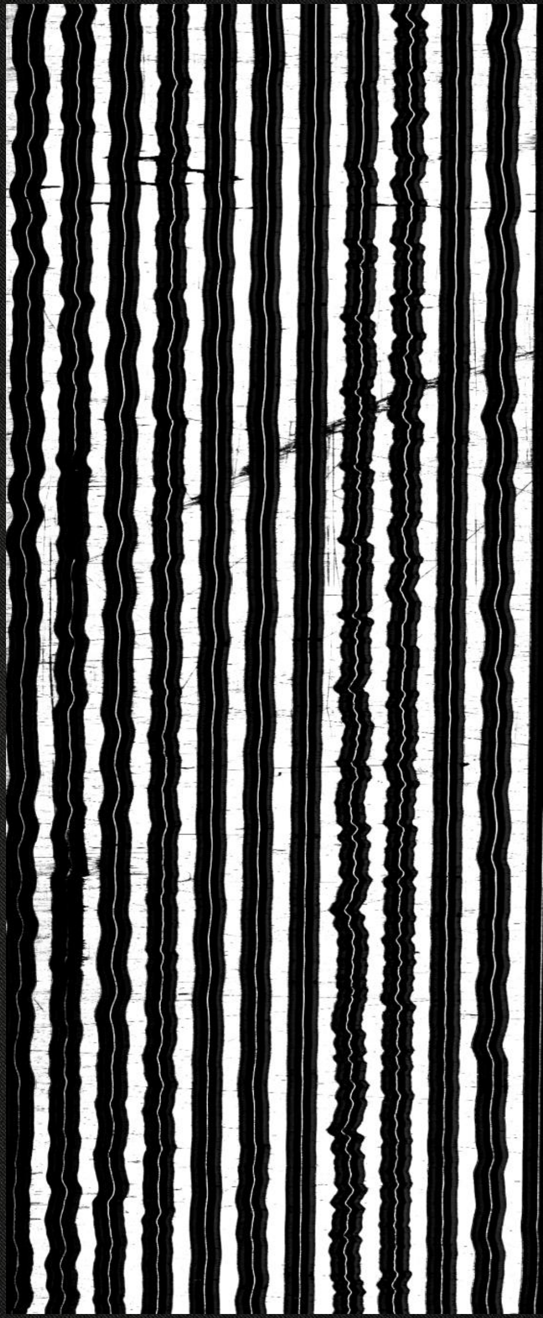


- Imaging machine
- Processing software
- Able to simulate play-back
- Preservation of records as pictures

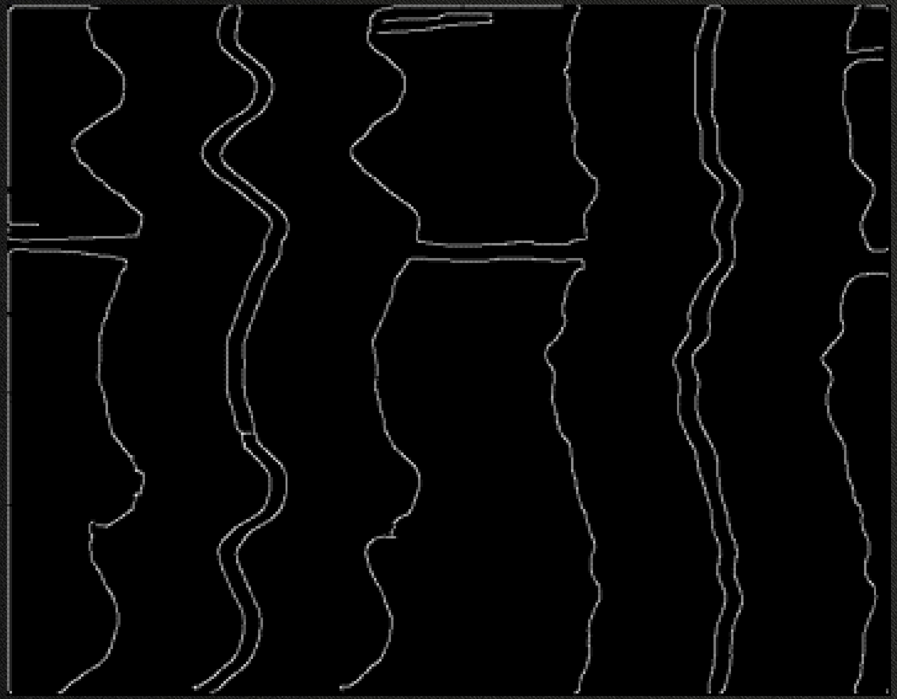
Taking pictures







Audio reconstruction



- Edge detection, middle of groove
- Perpendicular velocity, not position
- Affected by noise

Machine learning

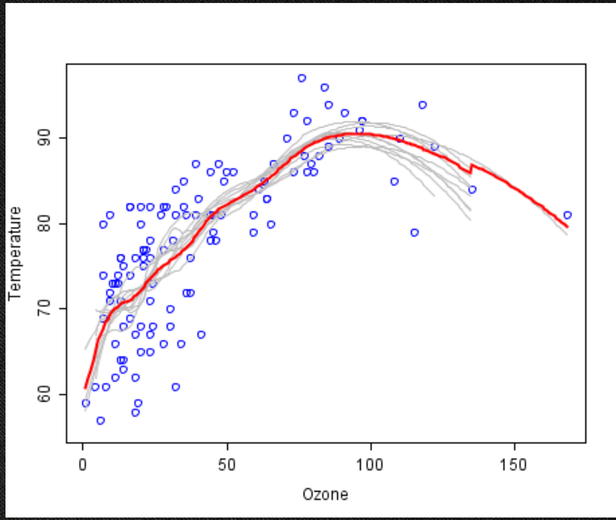
Classification : FNN, CNN, RNN, ResNet, …

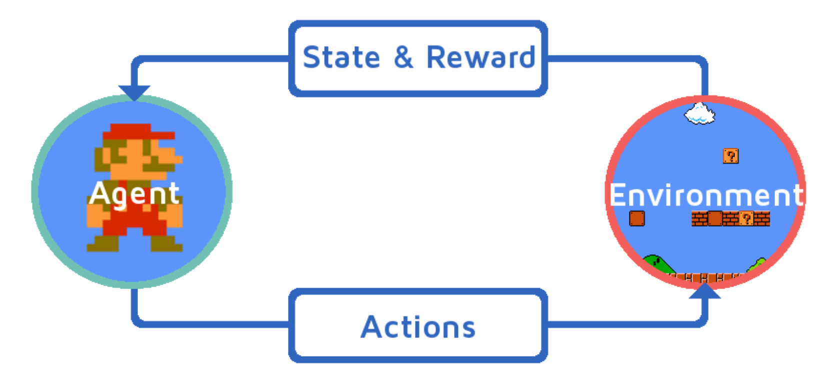
Regression : logistic, linear, LSTM, CNN …

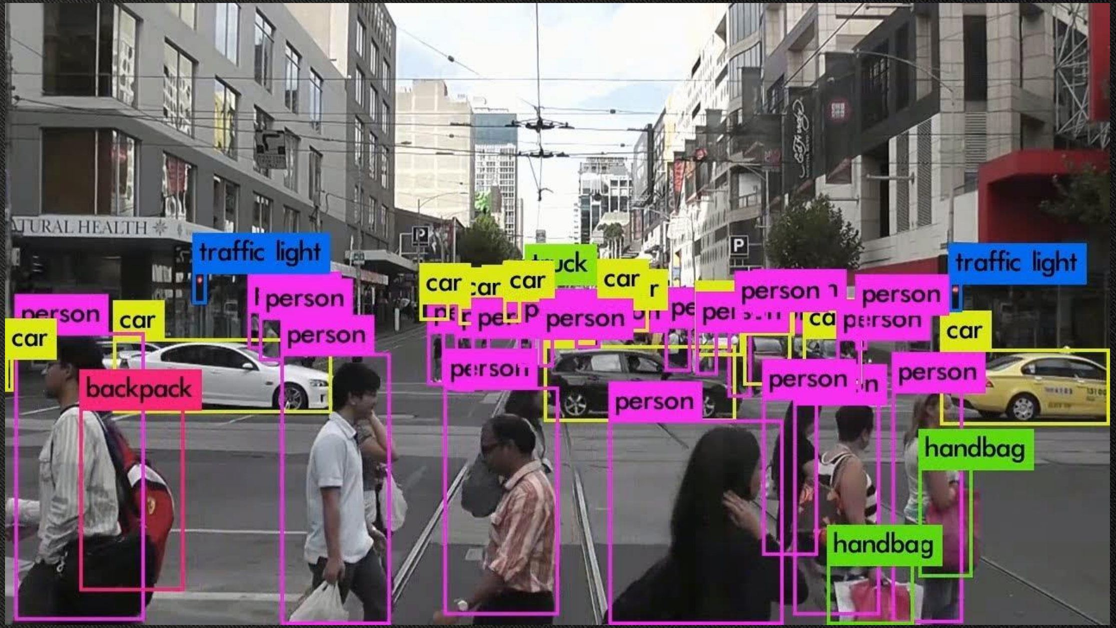
Reinforcement : Decision making

Generation : GAN, …

Denoising : Auto-encoder, …



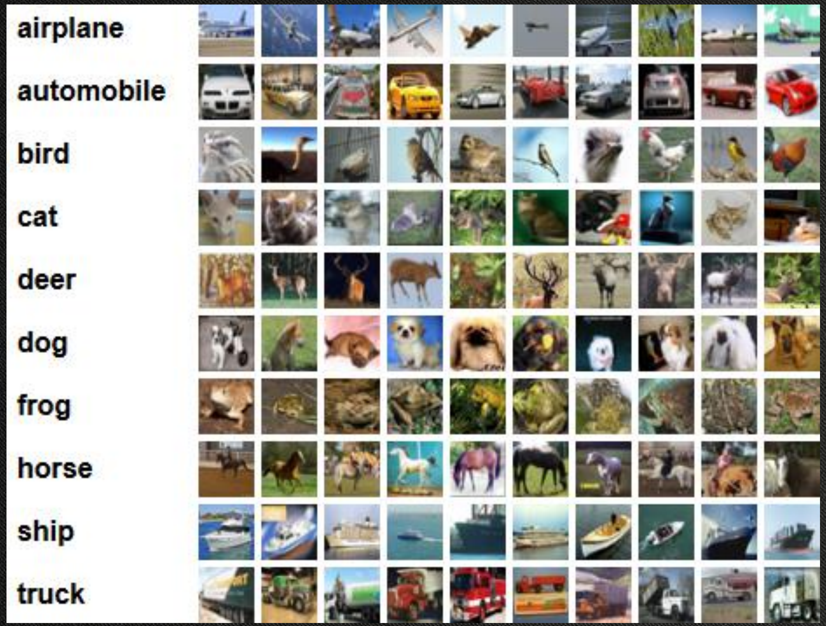




Objectives

- Improve the audio generated from images. Divided in prototypes for validation :
- Prototype 0 : Keras familiarization
- Prototype 1 : clean sound from clean sine grooves
- Prototype 2 : clean sound from noisy sine grooves
- Prototype 3 : noisy sound from disc images
- Prototype 4 : clean sound from disc images

Prototype 0



Keras :

- Makes implementation of machine learning modes simpler
- Lots of tools for data processing

CIFAR-10 :

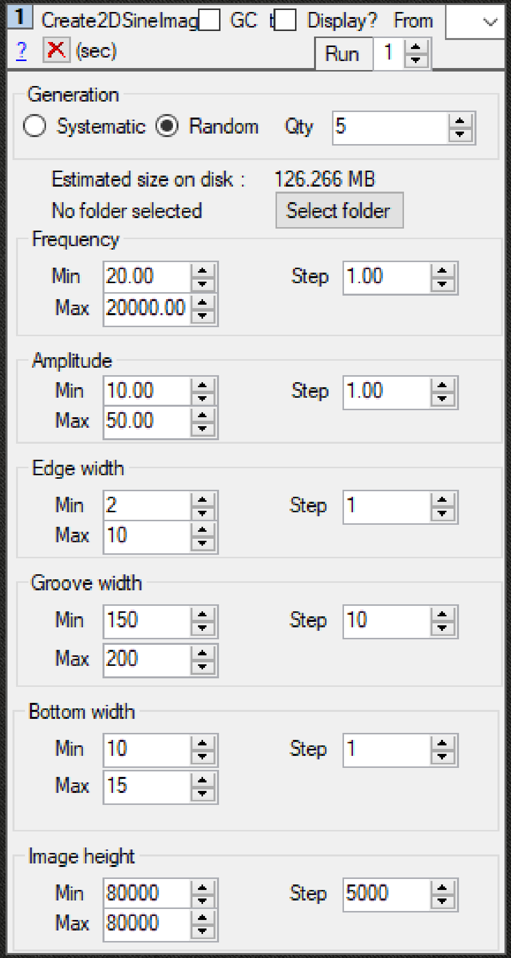
- 60’000 images in 10 classes

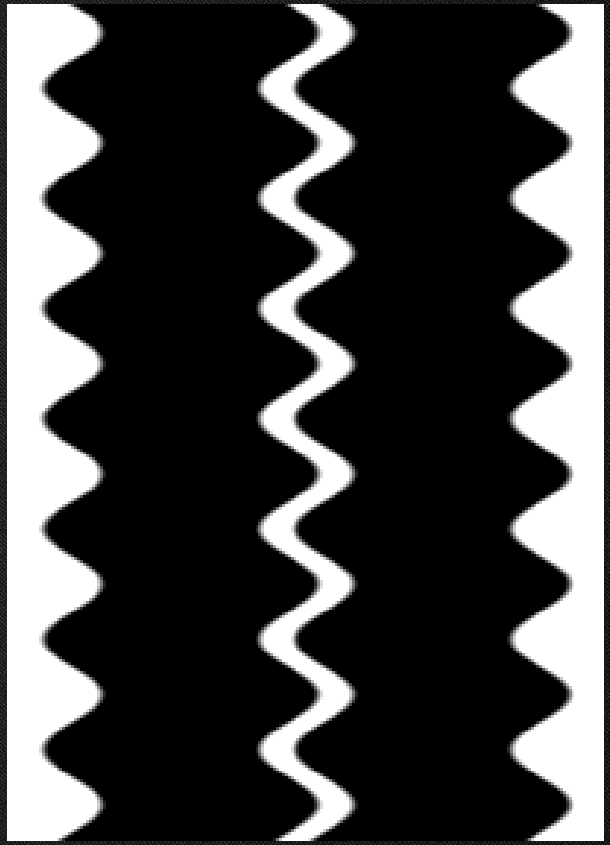
```
model = Sequential()
model.add(Conv2D(32, (3, 3), padding='same',
                 input_shape=x_train.shape[1:]))
model.add(Activation('relu'))
model.add(Conv2D(32, (3, 3)))
model.add(Activation('relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.25))
```

```
model.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          validation_data=(x_test, y_test),
          shuffle=True)
```

Prototype 1 - dataset

- Generation of pure sine groove images with Weaver (80’000 x 220)
- Randomized values for robustness of training
- Weaver’s audio reconstruction as target

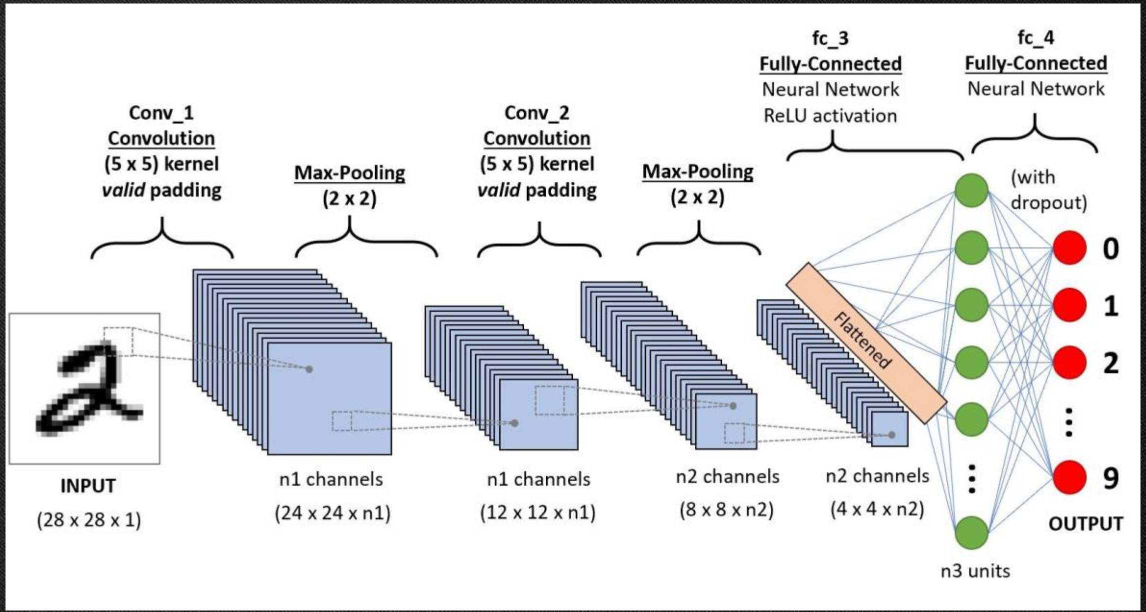




Prototype 1 – first version

- Convolutional neural network (same as prototype 0)
- Input : entire groove image - Target : entire sound wave

- Problems : Trillions of weights



Prototype 1 – second version

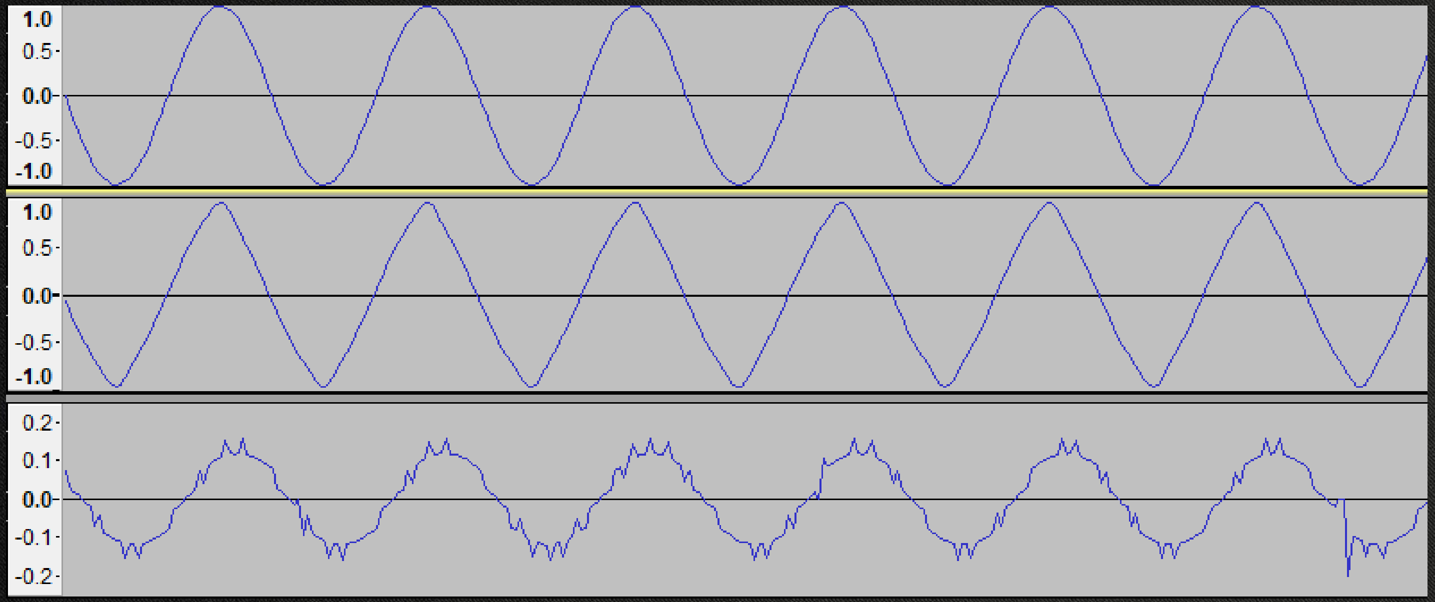
- Long Short-Term Memory network
- Input : block of rows
- Problem : no convergence
- Target : amplitude of sound (~= lateral velocity of stylus)

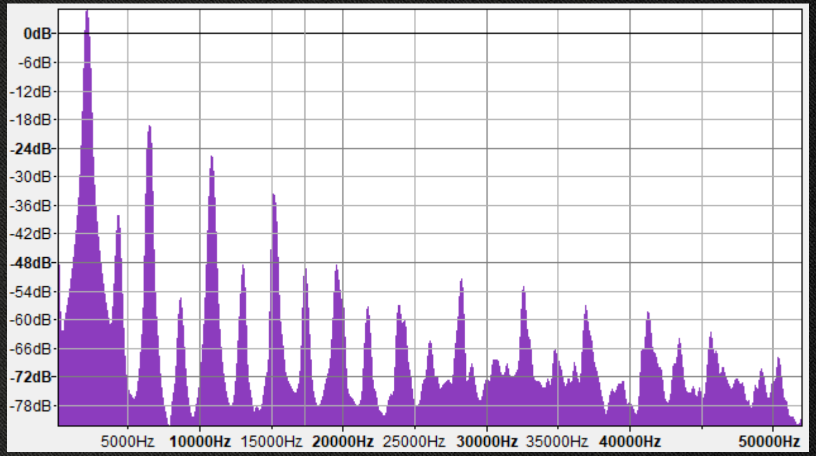
-> 0.8
-> 1.0
-> 0.6
-> 0.1
-> -0.3
-> -0.9
-> -1.0
-> -0.4
-> 0.0
-> 0.4

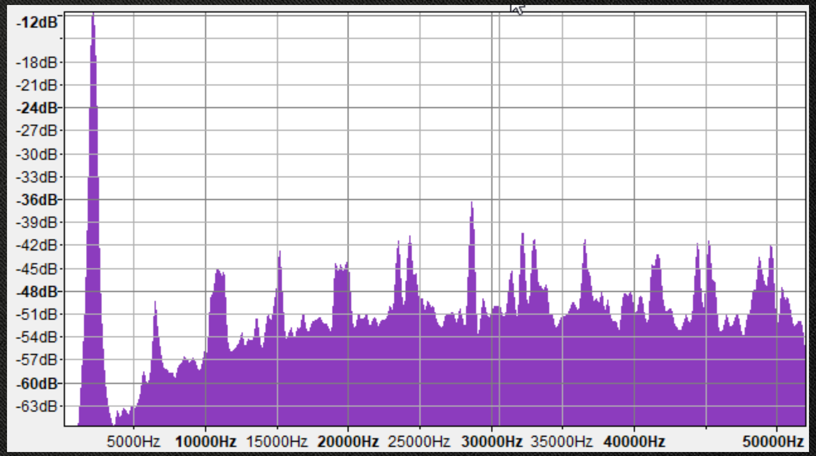
Prototype 1 – third version

- CNN again
- Input : block of rows
- Target : amplitude of sound (lateral velocity od stylus)
- Data preprocessing : Normalization of pixel values (0 to 1), generation of pure sine wave as target
- Promising results !

Prototype 1 – third version



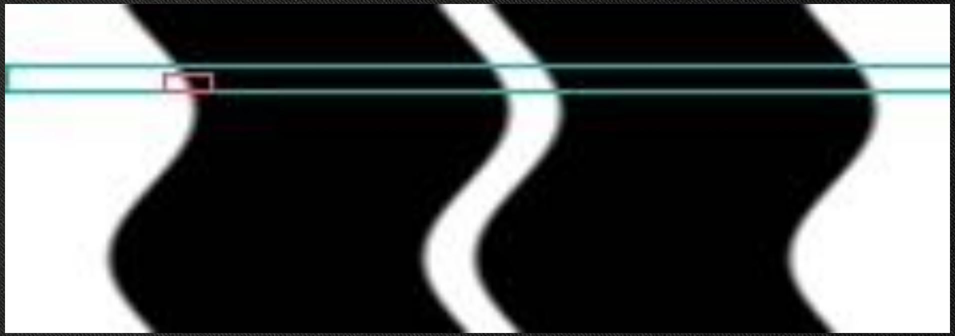




Prototype 1 – Fine tuning

Finding best values for all hyper-parameters :

- Number of rows in a block
- Number of predictions in a block
- Size of convolution filters
- Max pooling or not, what size
- Dropout or not, what rate
- Optimizer and its learning and decay rate
- Activation functions

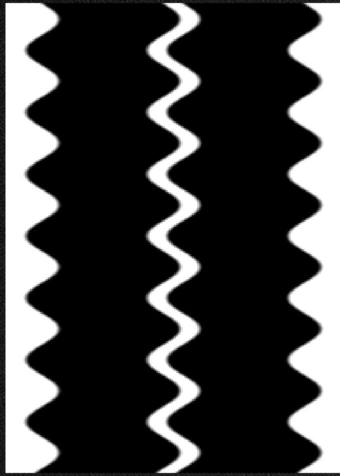


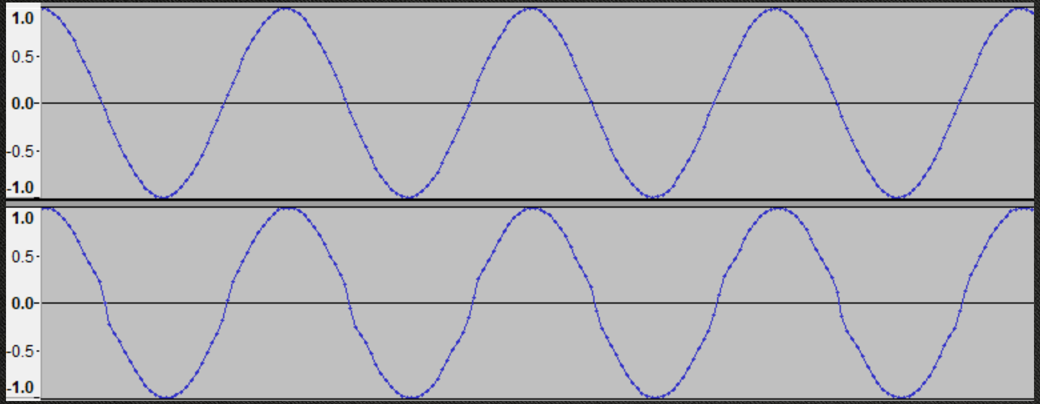
Prototype 1 – Final Results

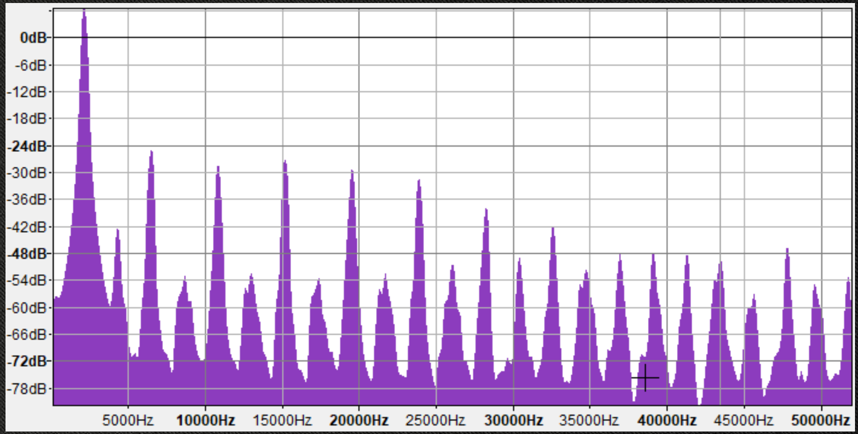
Best values = small values !

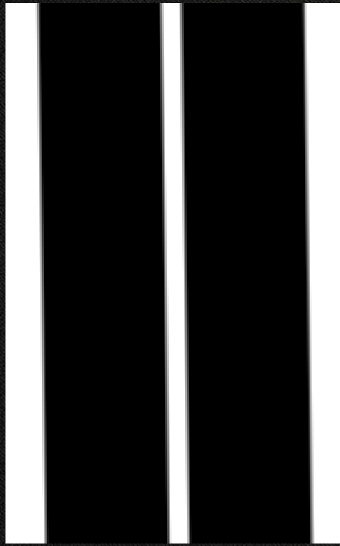
- Only 5 rows each time, with 1 prediction
- Convolutions of 3x3
- Max pooling of 2x2
- Dropout of 0.25 for first layers, 0.5 for last
- Close to default values for RMSprop optimizer
- ReLu for first layers, tanh for last

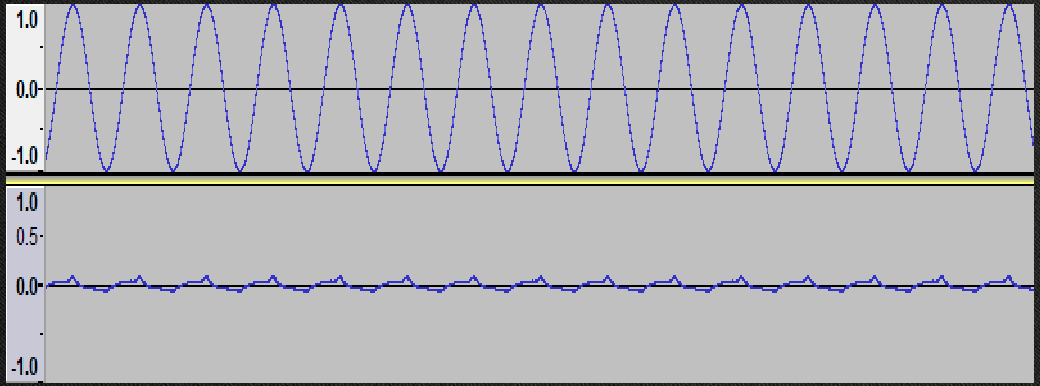
Prototype 1 – Final Results



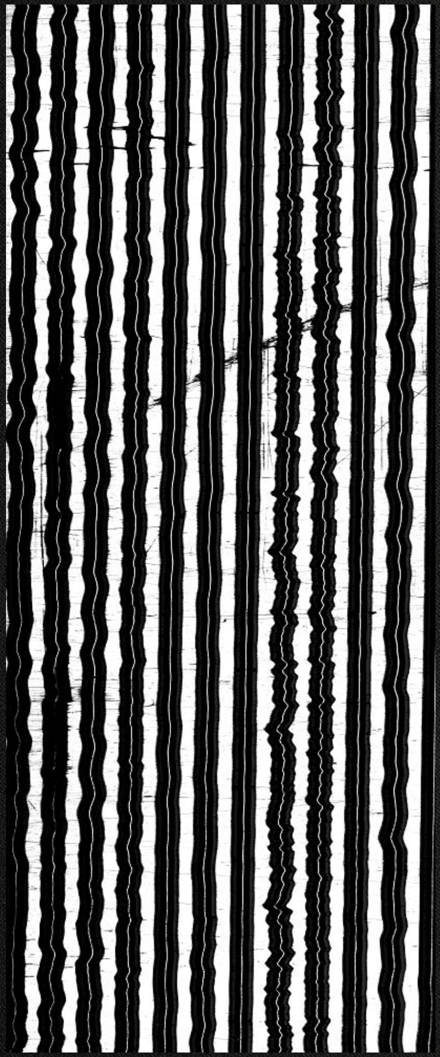


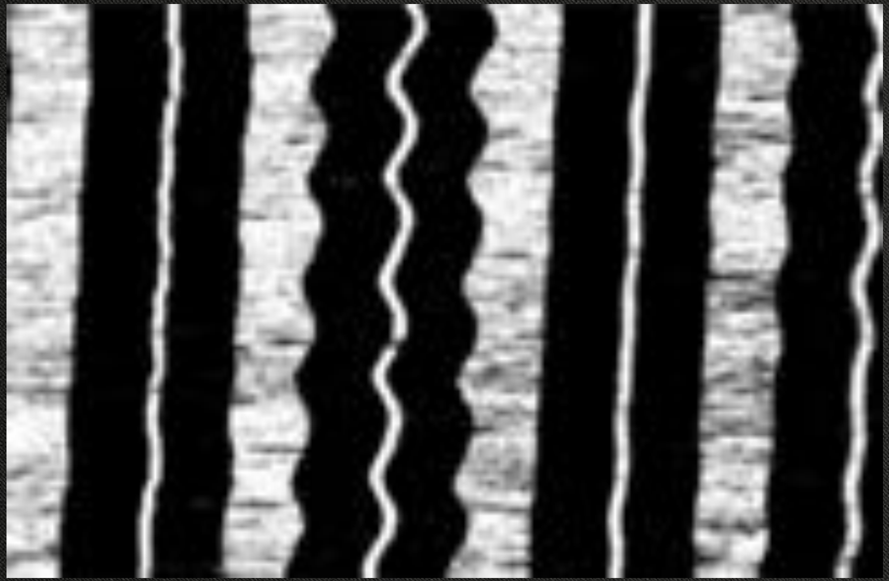


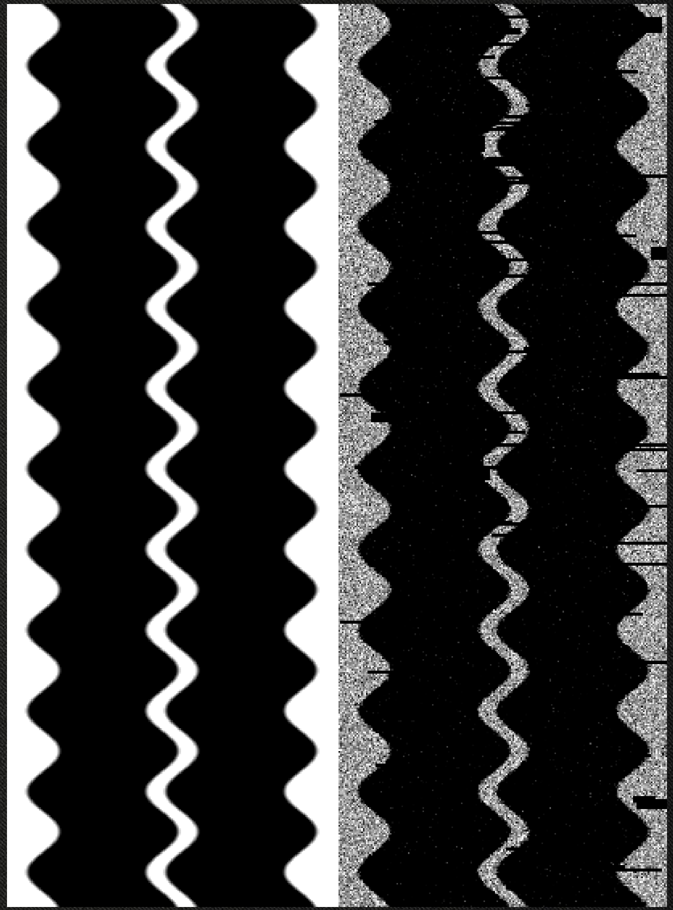




Prototype 2 – Noisy images







Prototype 2 – Fine tuning again

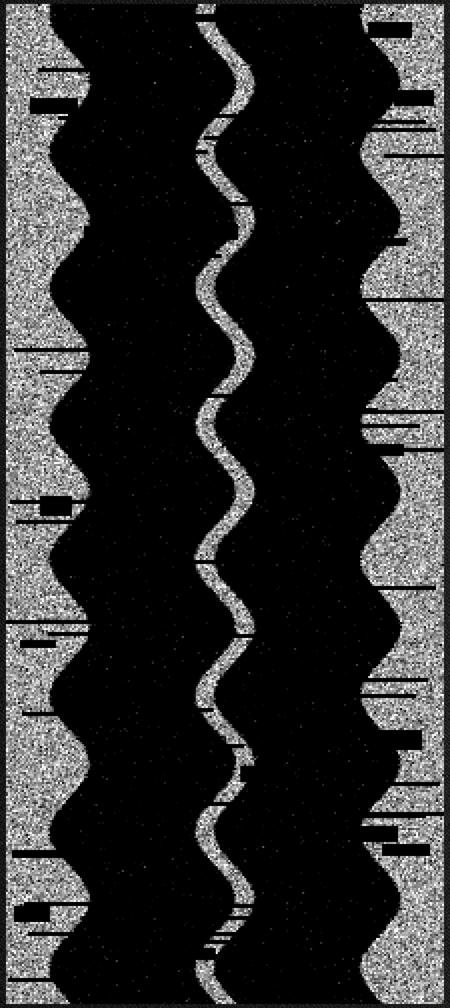
- Properties are different
- Maybe seeing more rows can help correct defaults
- The optimizer is bad : results are fast but not improving over time.

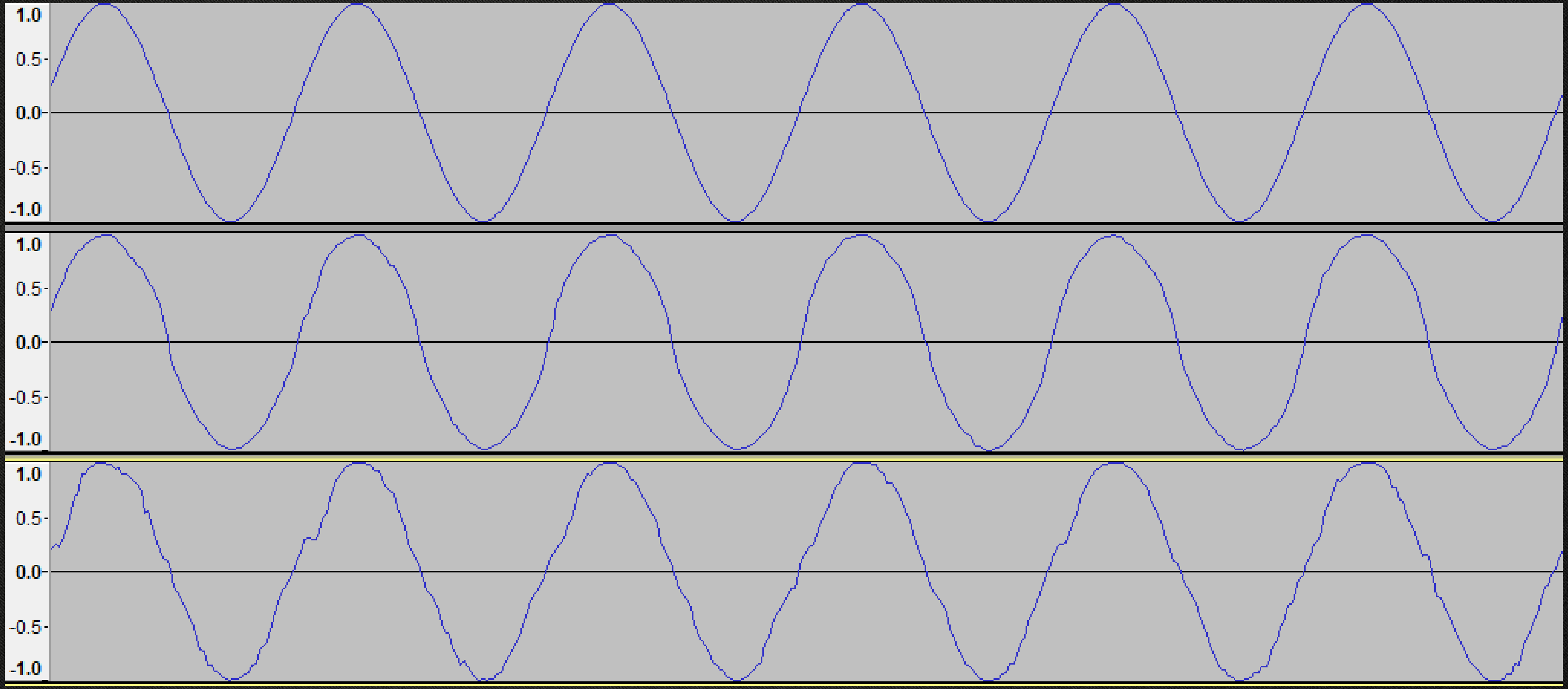
- General architecture stays the same

Prototype 2 – Results

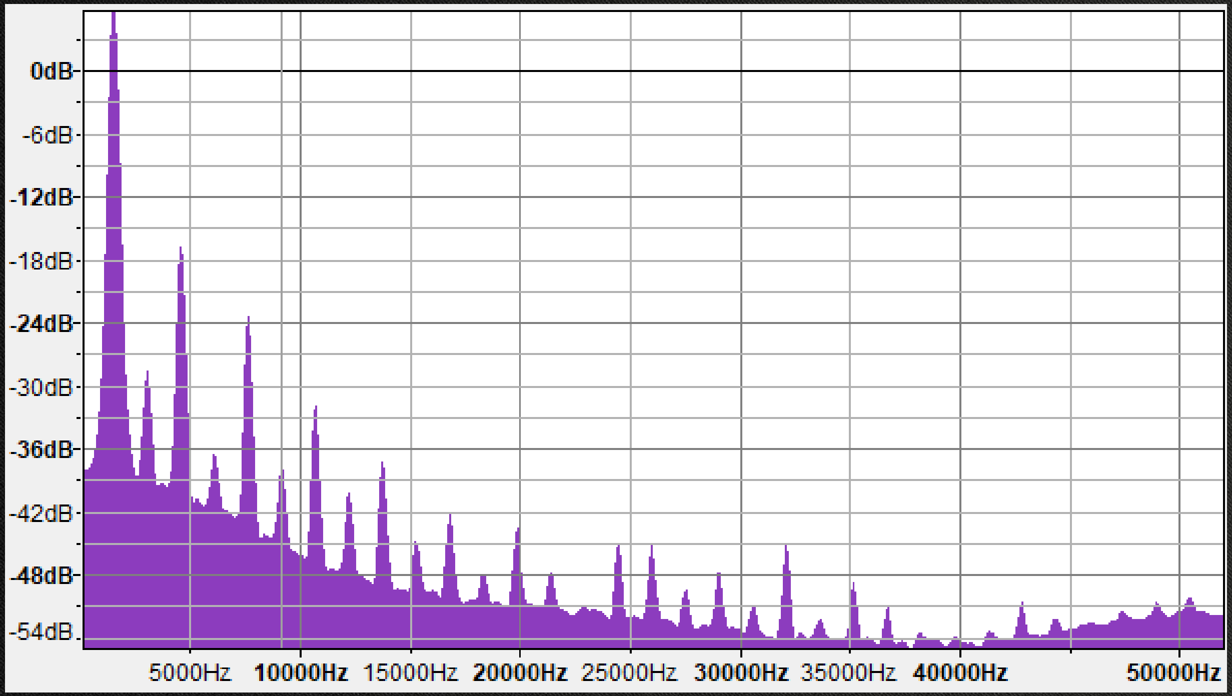
- Best results with 15 rows of pixels
- RMSProp and Adam optimizers have good but different results, slightly improving over time

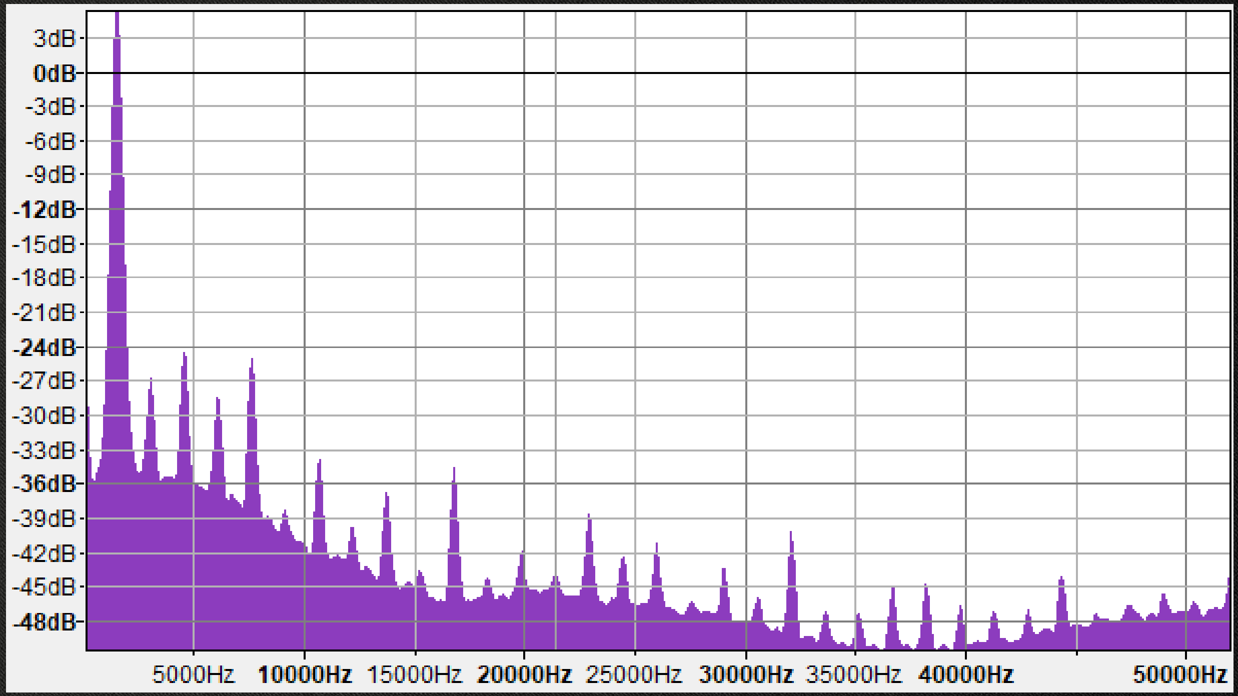
Prototype 2 – Results





Prototype 2 – Results





Next steps

- Using actual disc images
- Transfer learning or training from the start
- Finish report and evaluate project