Satellite Image Classification

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Motivation

Build a machine learning framework to differentiate any satellite image by trained models

Highlights

- Different machine learning algorithms including deep neural network, CNN, and GANs models were deployed on a huge satellite image dataset.
- Model architecture and performance were explicitly evaluated.
- The best model, CNN model, was applied to classify new images successfully.

Data Sources

- Original Paper

Saikat Basu, Sangram Ganguly, Supratik Mukhopadhyay, Robert Dibiano, Manohar Karki and Ramakrishna Nemani, DeepSat - A Learning framework for Satellite Imagery, ACM SIGSPATIAL 2015.

http://csc.lsu.edu/~saikat/deepsat/

- Satellite Images CSV file

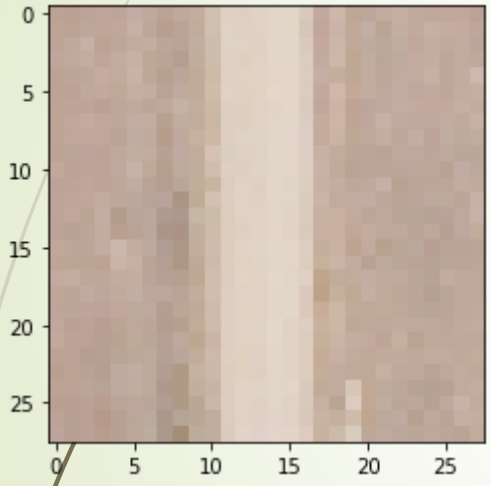
https://www.kaggle.com/arpandhatt/satellite-image-classification

Exploratory Data Analysis

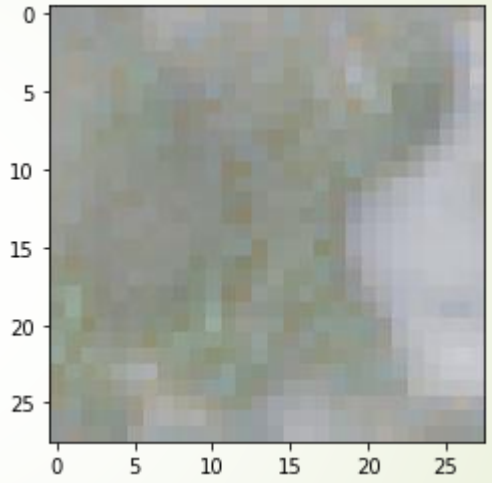
SAT-4 Image: 500,000, training: 400,000 (4/5), test: 100,000 (1/5)

Four categories: barren land, trees, grassland, other (in this order)

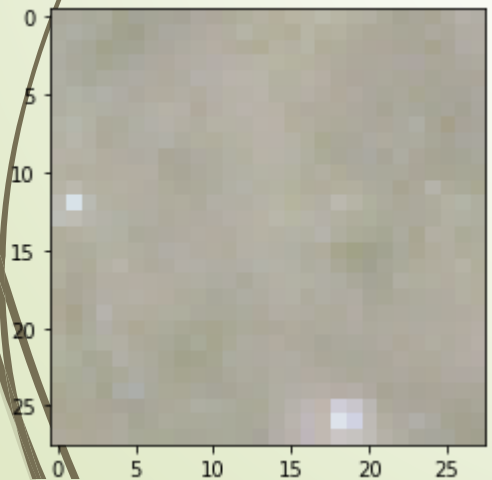
Each image: 28x28x4 (RGB and Infra).



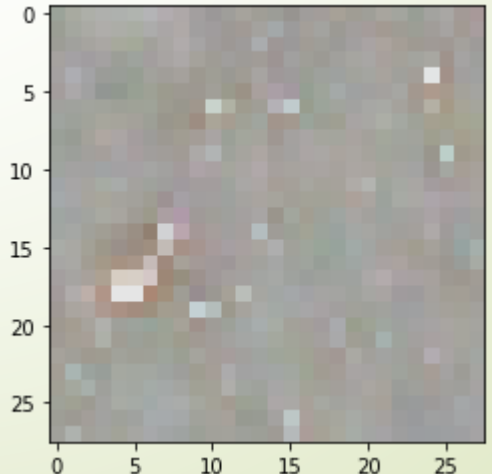
Barren land
(label: 0)
(104,465)



Trees
(label: 1)
(81,118)

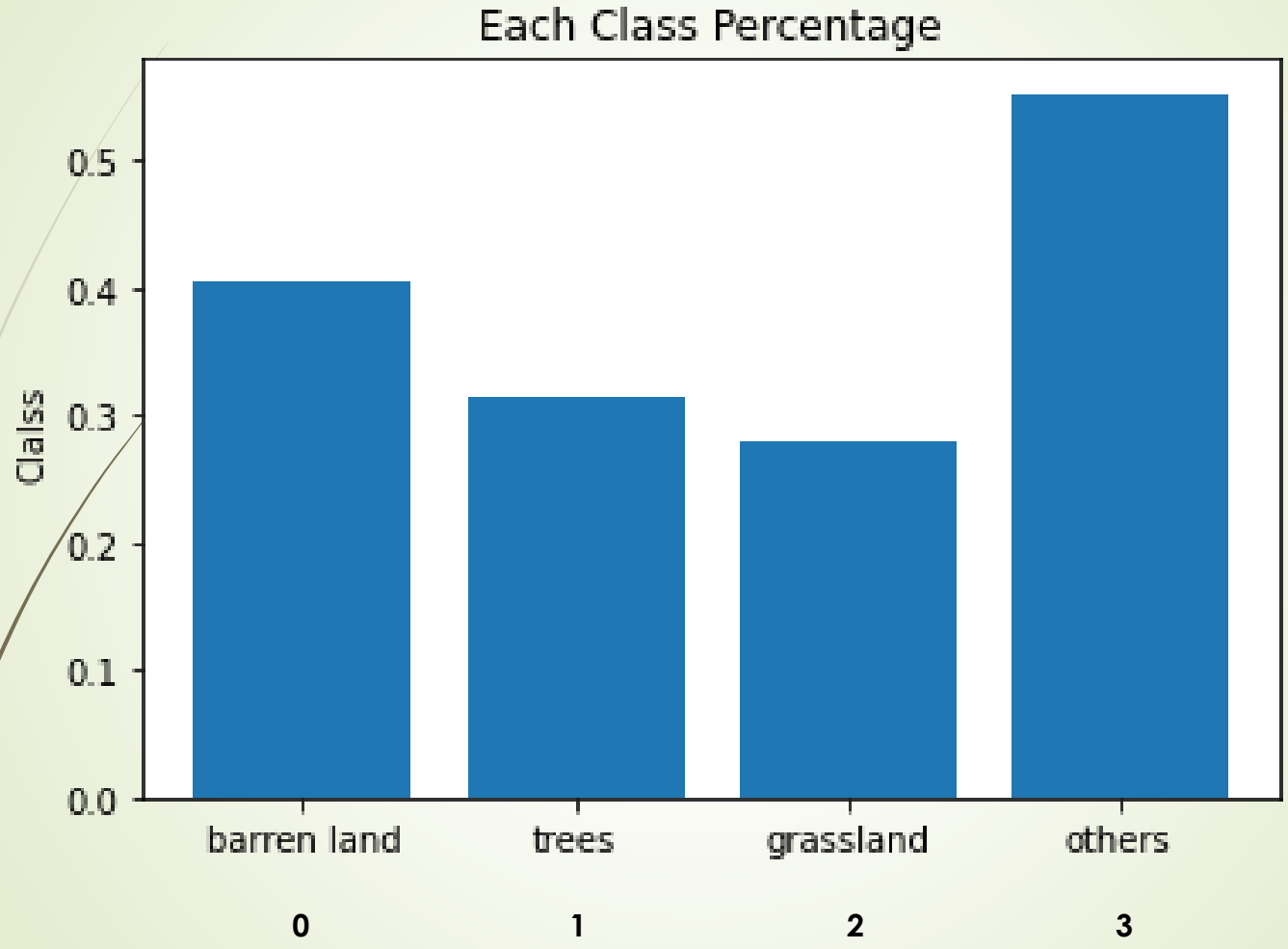


Grassland
(lable: 2)
(72,017)



Other
(lable: 3)
(142,400)

Samples are balanced

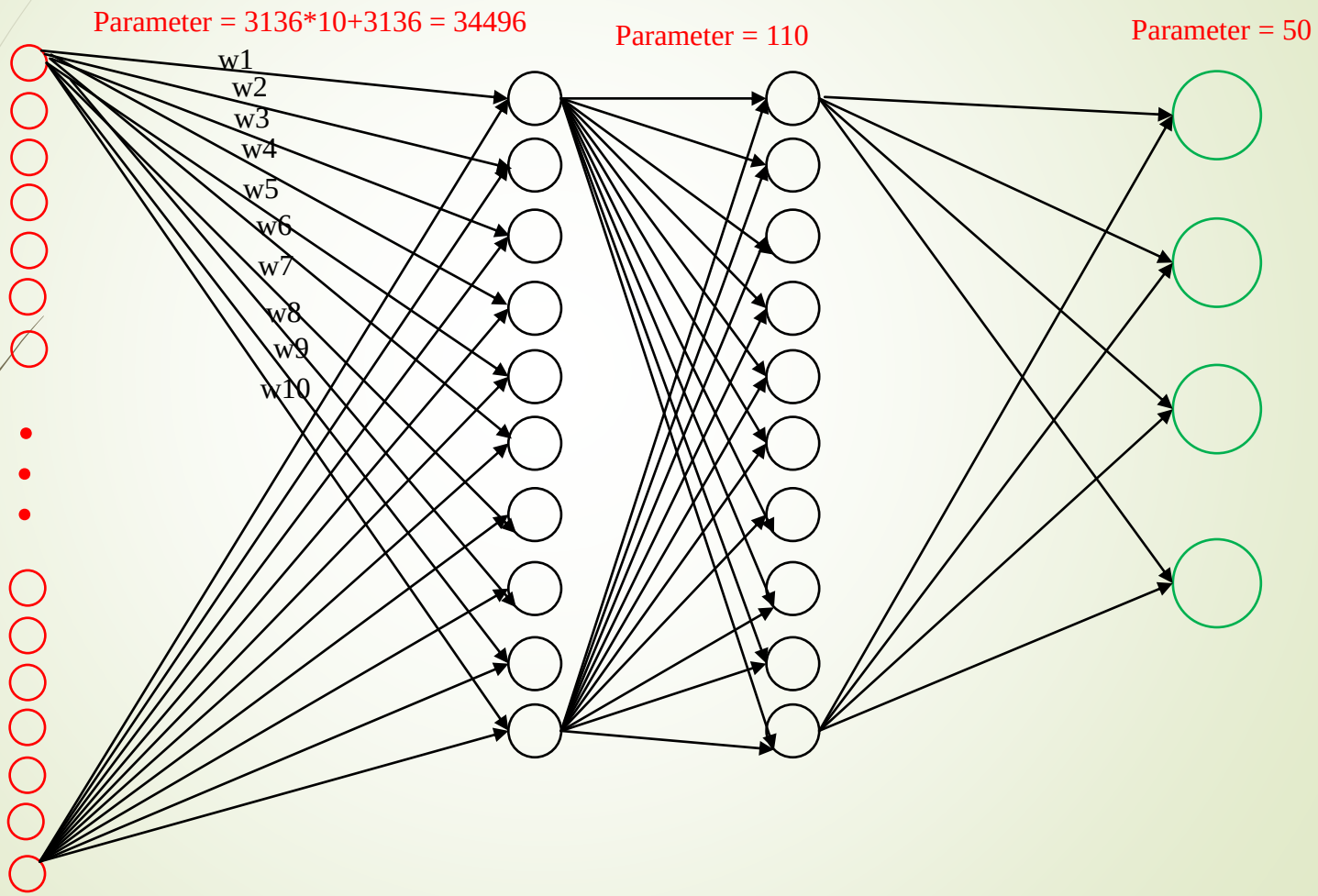


Model 1 - Deep Neural Network

Input

Hidden
(2 layers)

Output



3136 = 28x28x4

10

10

4

Model Architecture

Model: "sequential"

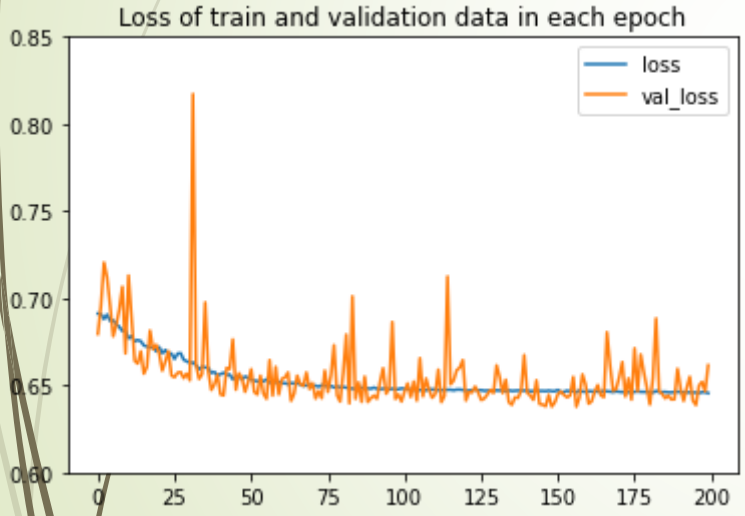
Layer (type)	Output Shape	Param #
dense (Dense)	(None, 10)	31370
dense_1 (Dense)	(None, 10)	110
dense_2 (Dense)	(None, 4)	44

Total params: 31,524
Trainable params: 31,524
Non-trainable params: 0

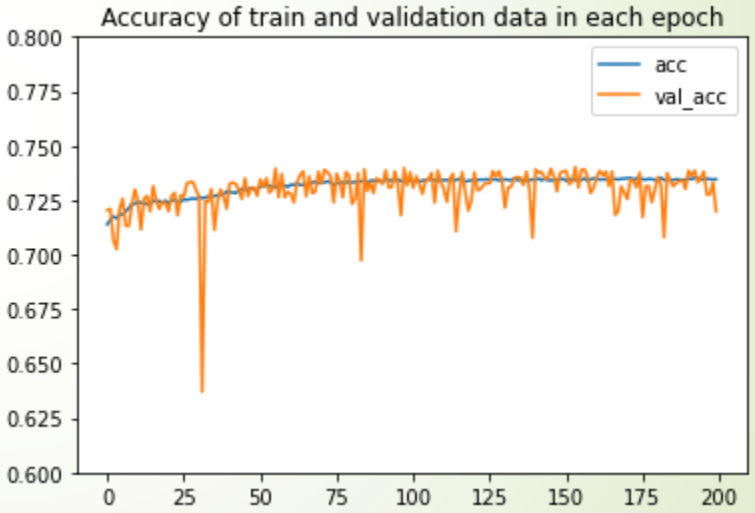
Model Performance

Training Data

Loss Function



Accuracy

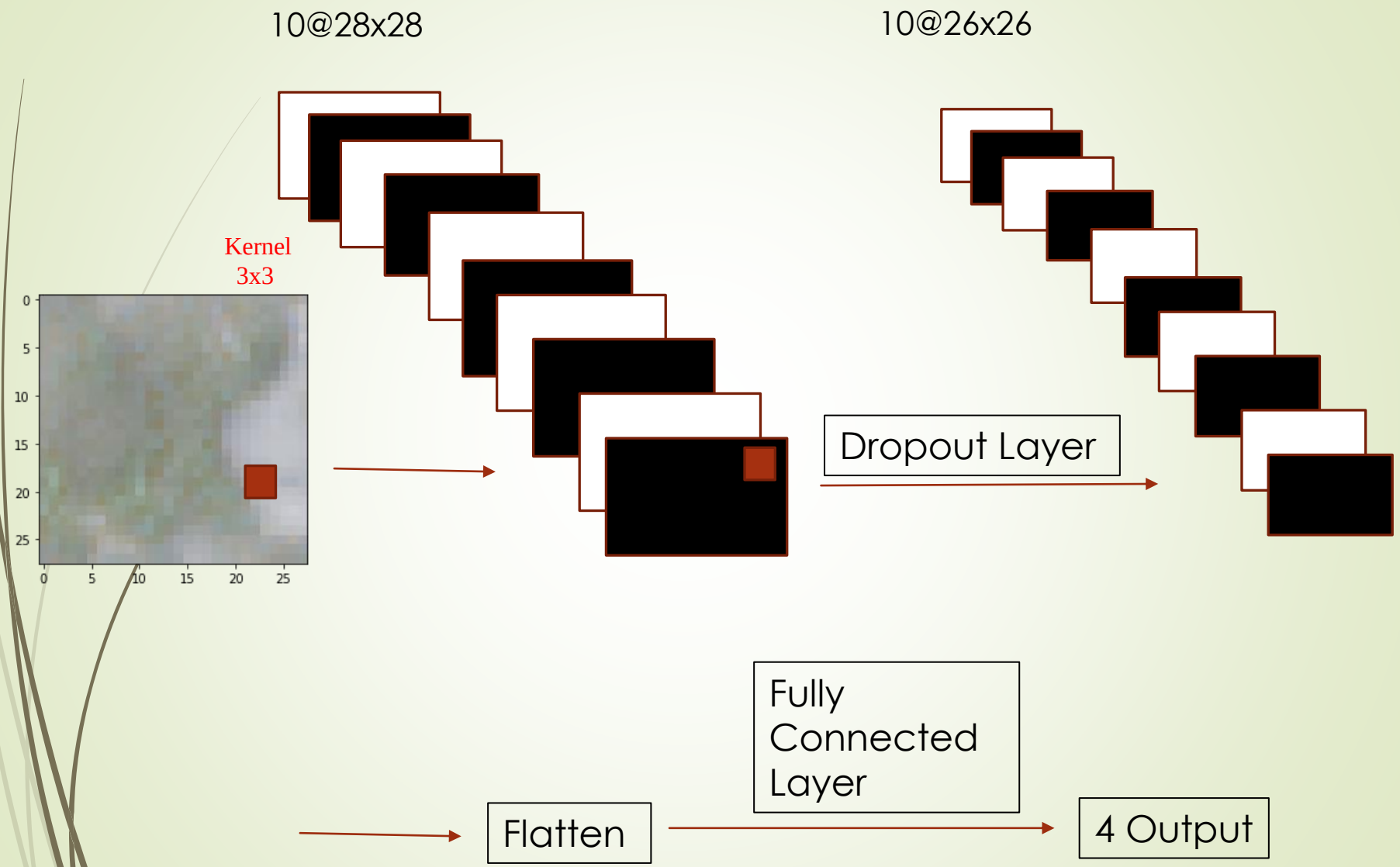


Model Evaluation

```
Deep Neural Network: Accuracy=0.719
Deep Neural Network: f1-score=0.704
              precision    recall  f1-score   support

           0       0.84      0.92      0.88     26189
           1       0.68      0.84      0.75     20231
           2       0.56      0.31      0.40     17946
           3       0.70      0.70      0.70     35634

    accuracy                           0.72    100000
   macro avg       0.69      0.70      0.68    100000
weighted avg       0.71      0.72      0.70    100000
```

Confusion Matrix

Model 2 – Convolutional Neural Network (CNN)



Model Architecture

Model: "sequential_2"

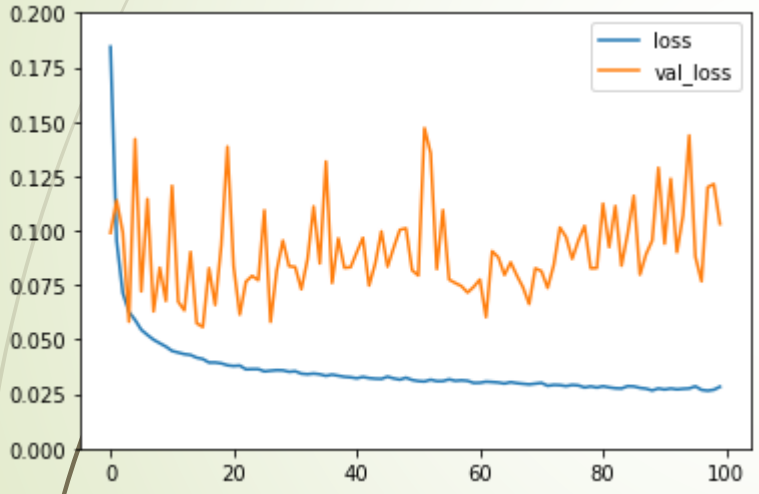
Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 28, 28, 10)	370
dropout (Dropout)	(None, 28, 28, 10)	0
conv2d_1 (Conv2D)	(None, 26, 26, 10)	910
flatten (Flatten)	(None, 6760)	0
dense_6 (Dense)	(None, 4)	27044

Total params: 28,324
Trainable params: 28,324
Non-trainable params: 0

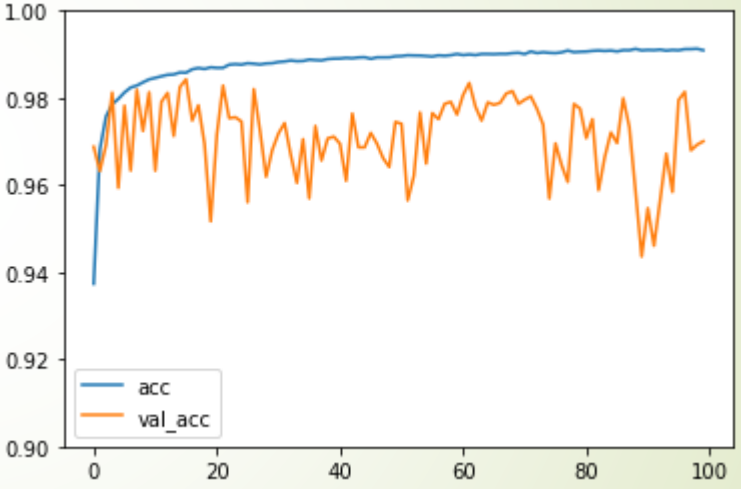
Model Performance

Training Data

Loss Function



Accuracy



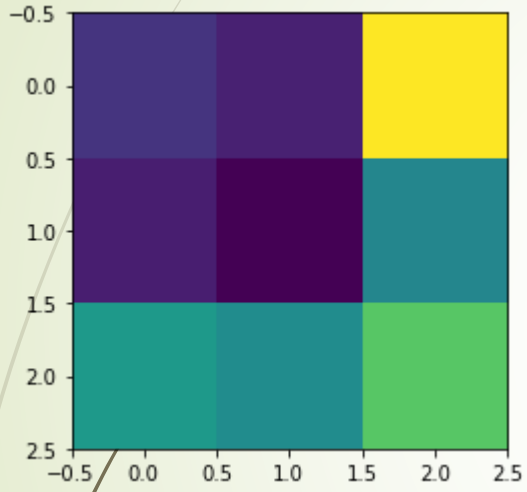
Model Evaluation

```
CNN: Accuracy=0.971
CNN: f1-score=0.704
              precision    recall  f1-score   support

           0       0.99      0.93      0.96     26189
           1       0.99      0.99      0.99     20231
           2       0.89      0.99      0.93     17946
           3       0.99      0.98      0.99     35634

    accuracy                           0.97    100000
   macro avg       0.97      0.97      0.97    100000
weighted avg       0.97      0.97      0.97    100000
```

Confusion Matrix

Model Interpretation

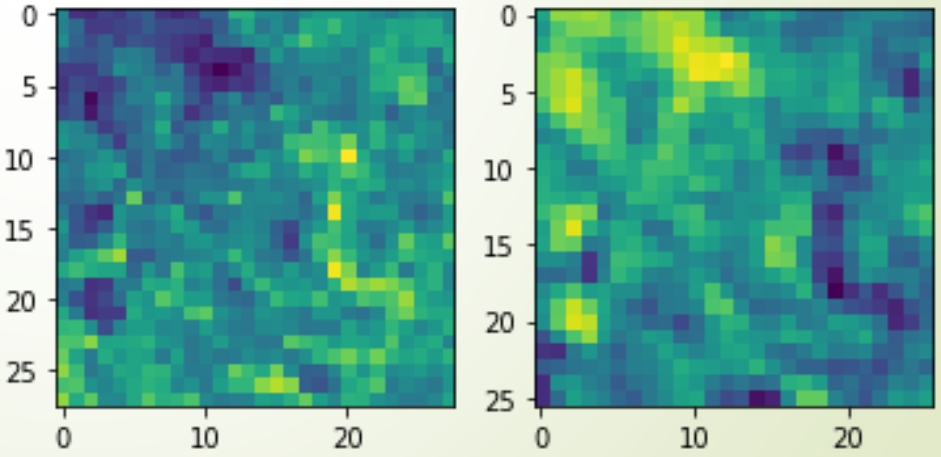
Kernel – Layer1



Image

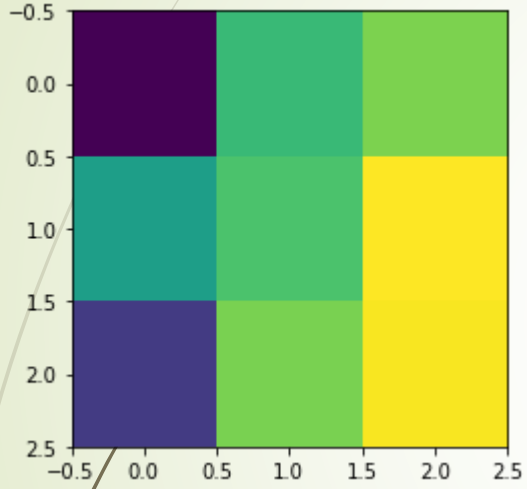
Before

After



Model Interpretation

Kernel – Layer2



Image

Before

After

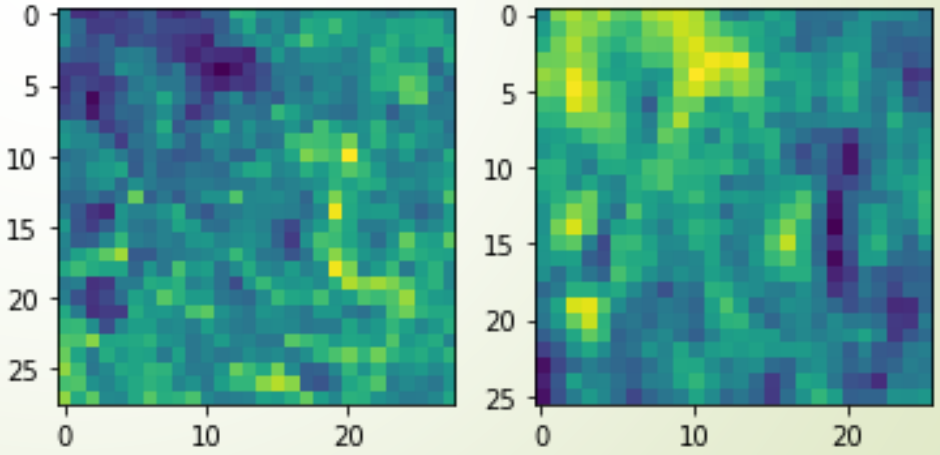


Image for Testing

['barren/1.jpg']

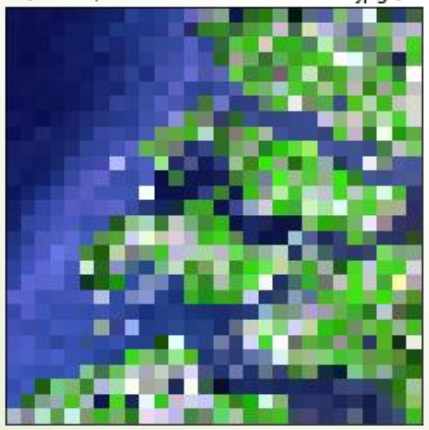
['barren/dfghd.jpg']

['grass/aed.jpeg']

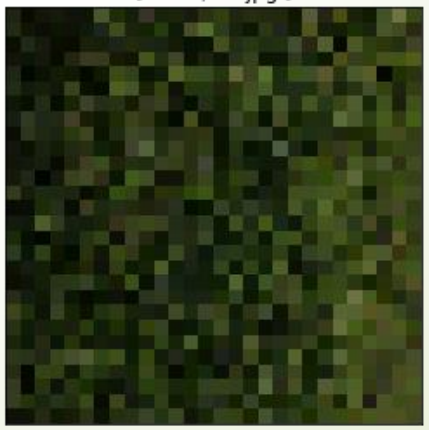
['grass/dfef.jpg']

['other/1dr.jpg']

['other/aster-netherlands-dikes.jpg']



['trees/sdf.jpg']



['trees/th.jpg']

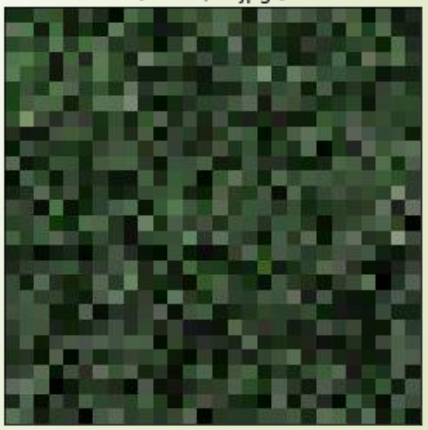
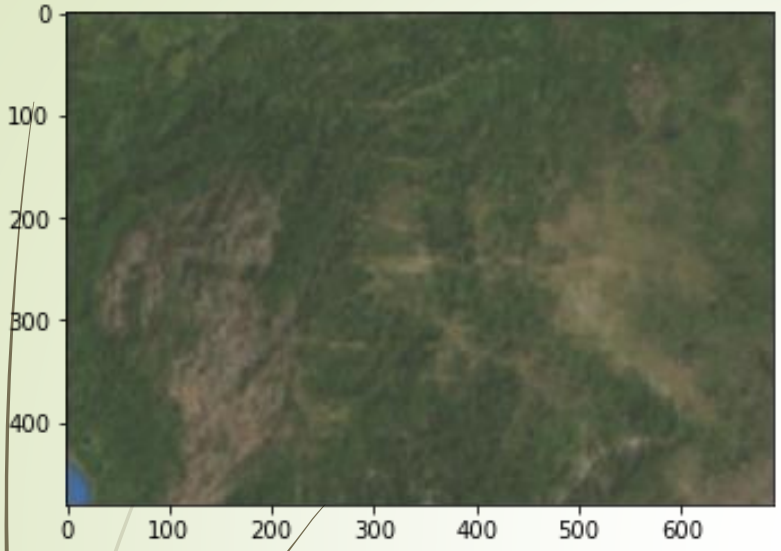
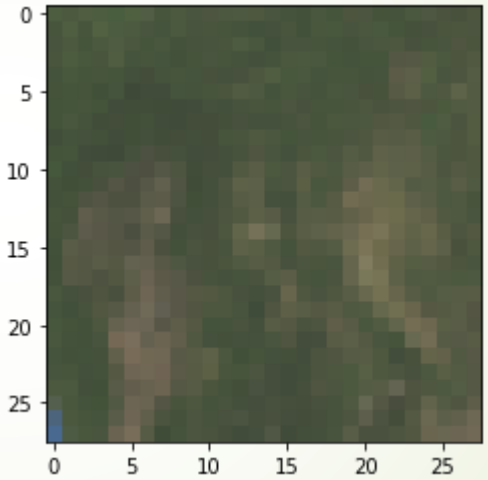


Image Prediction

- **Downloaded 9 satellite images from internet as brand new testing data sets;**
- **Feed them into the CNN model to predict the class of each image;**
- **Prediction results showed that all 9 images are others.**
- **I think the reason that CNN model does not produce the accurate results is because all input images only have 3 color channels. I had to artificially add the 4^{th} color channel as zero or a mean of the 3 RGB channels.**

Results





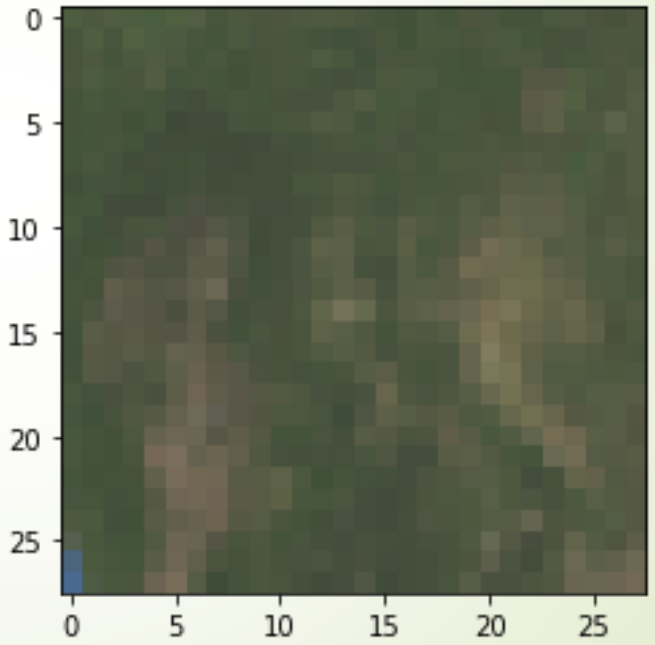
Prediction: 2 - Grassland

Discussion

3 channels

Information loss

4 channels



Prediction: 3 – Other

Prediction: 2 – Grassland

Summary

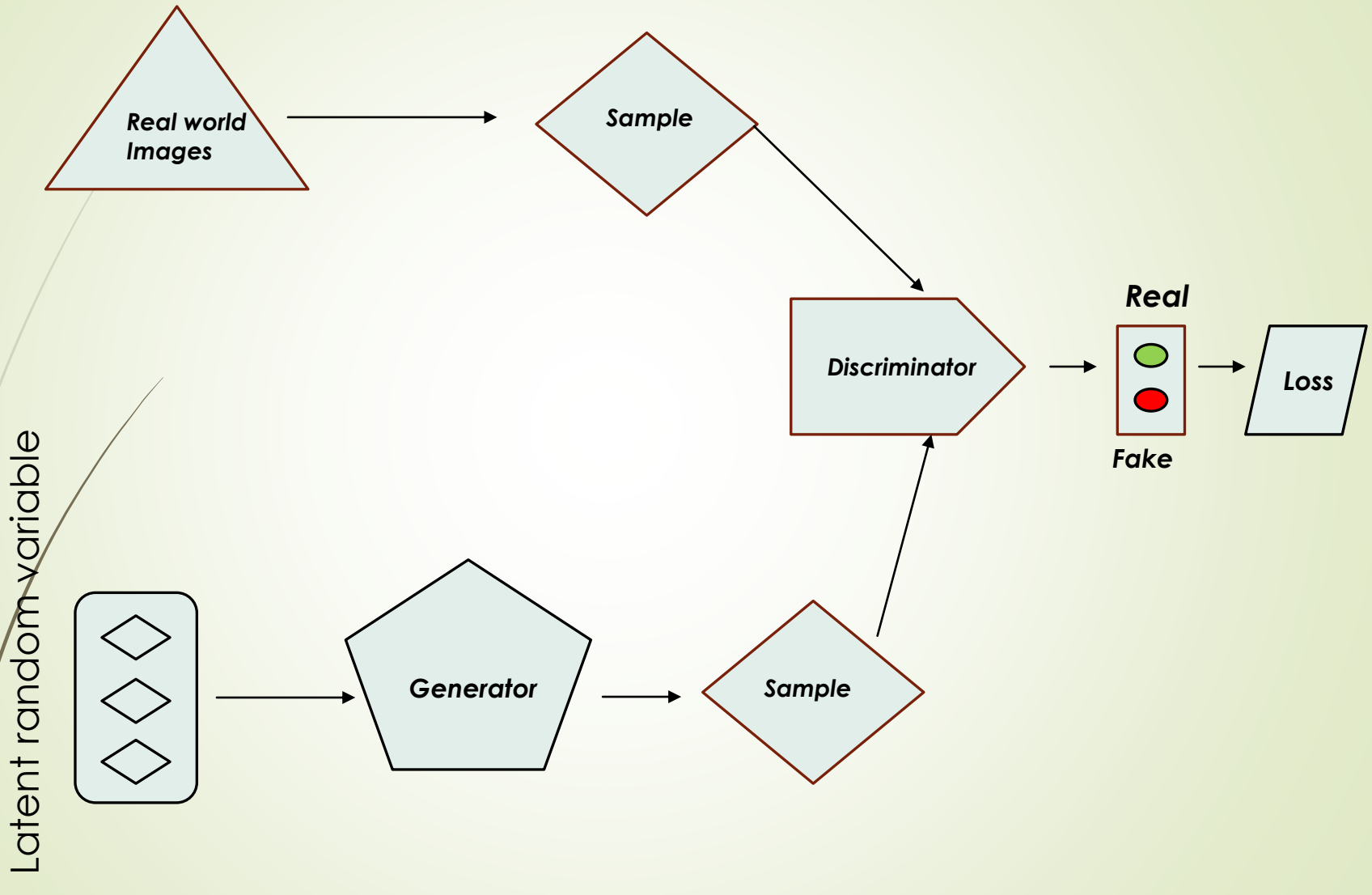
- **Trained a large dataset using general deep neural network and CNN model, CNN is much better in terms of accuracy;**
- **Tested model on random pictures. It demonstrated the importance to have the infra color information in the satellite image. Samples need to be prepared and pre-processed to match the training input for more accurate prediction.**

Future Work

- **Label more features, can train SAT-6 data;**
- **Train model with 3 color channels only;**
- **Use satellite image with more channels to train classification model;**
- **Try U-Net to do object detection;**
- **Test GANs model to generate synthetic images for training.**

Preliminary GANs Results

Generative Adversarial Networks (GANs)

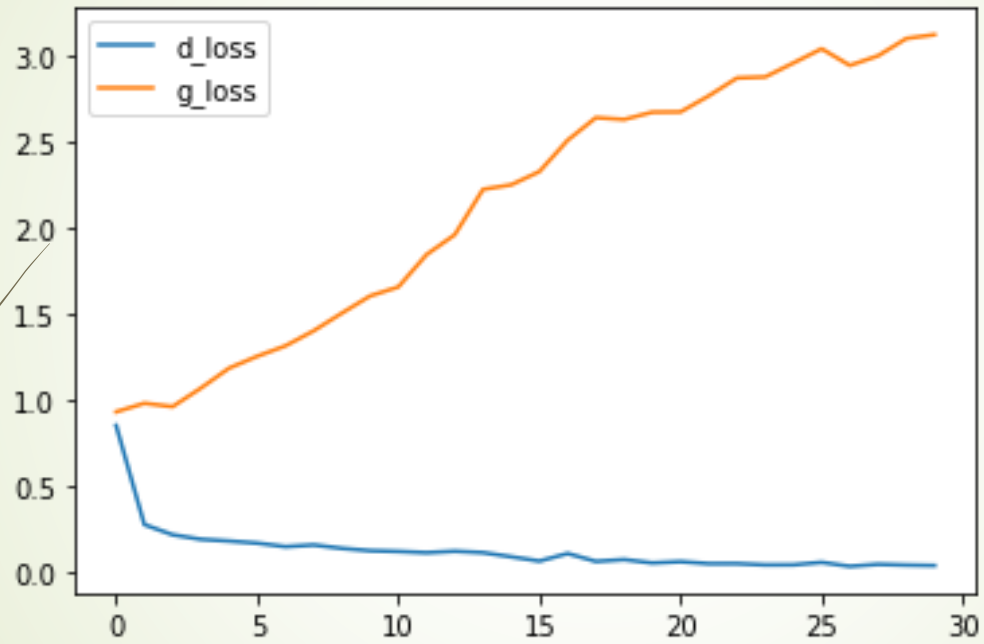


Model Architecture

```
Model: "functional_11"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_6 (InputLayer)         [(None, 100)]             0
_________________________________________________________________
functional_9 (Functional)    (None, 3136)              3321920
_________________________________________________________________
functional_7 (Functional)    (None, 1)                 1737729
=================================================================
Total params: 5,059,649
Trainable params: 3,319,872
Non-trainable params: 1,739,777
_________________________________________________________________
```

Model Performance

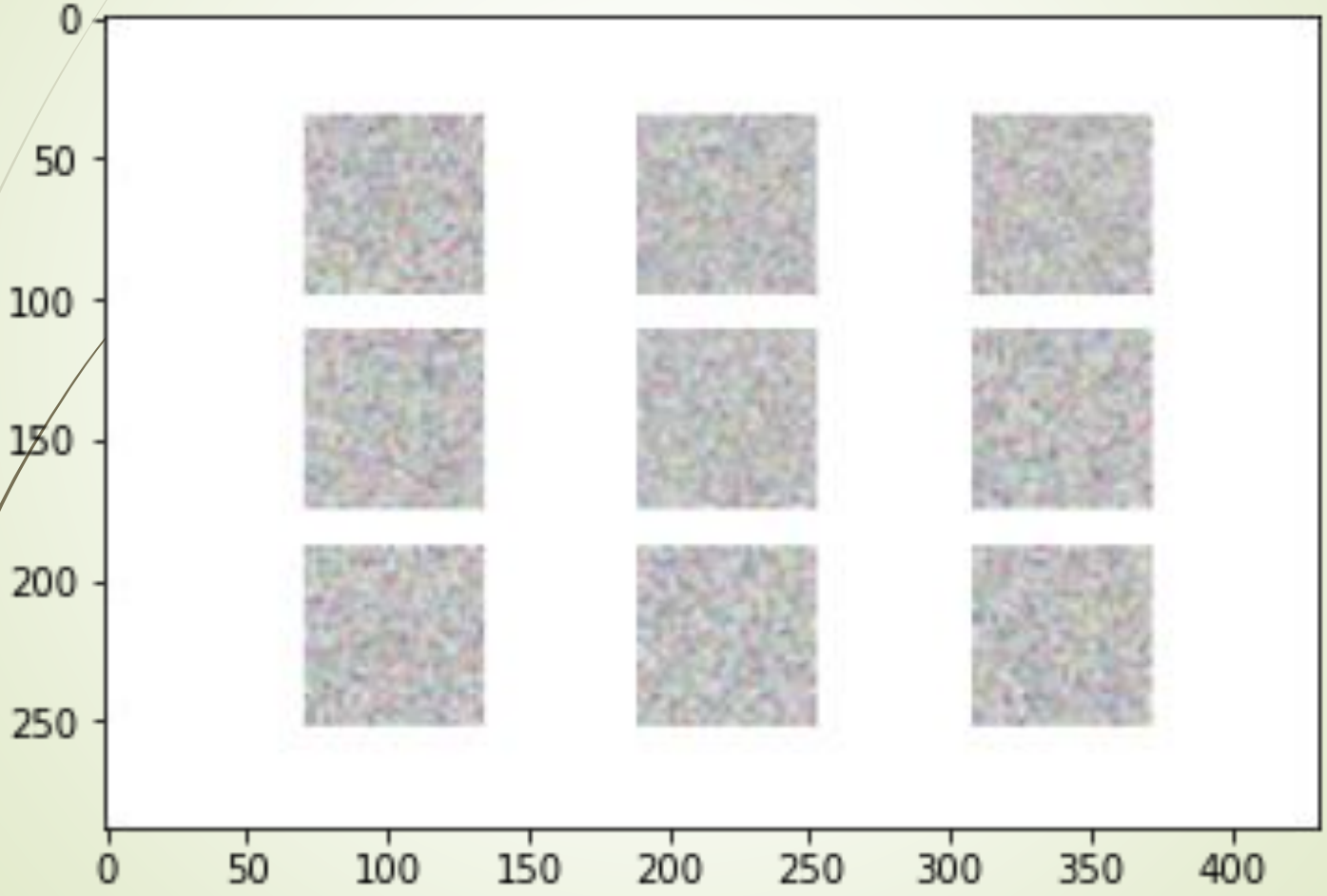
Loss Function



Discriminator converge very quickly, while generator is far from converging. Only run 300 epochs, need more epochs. Need cloud computation or GPU.

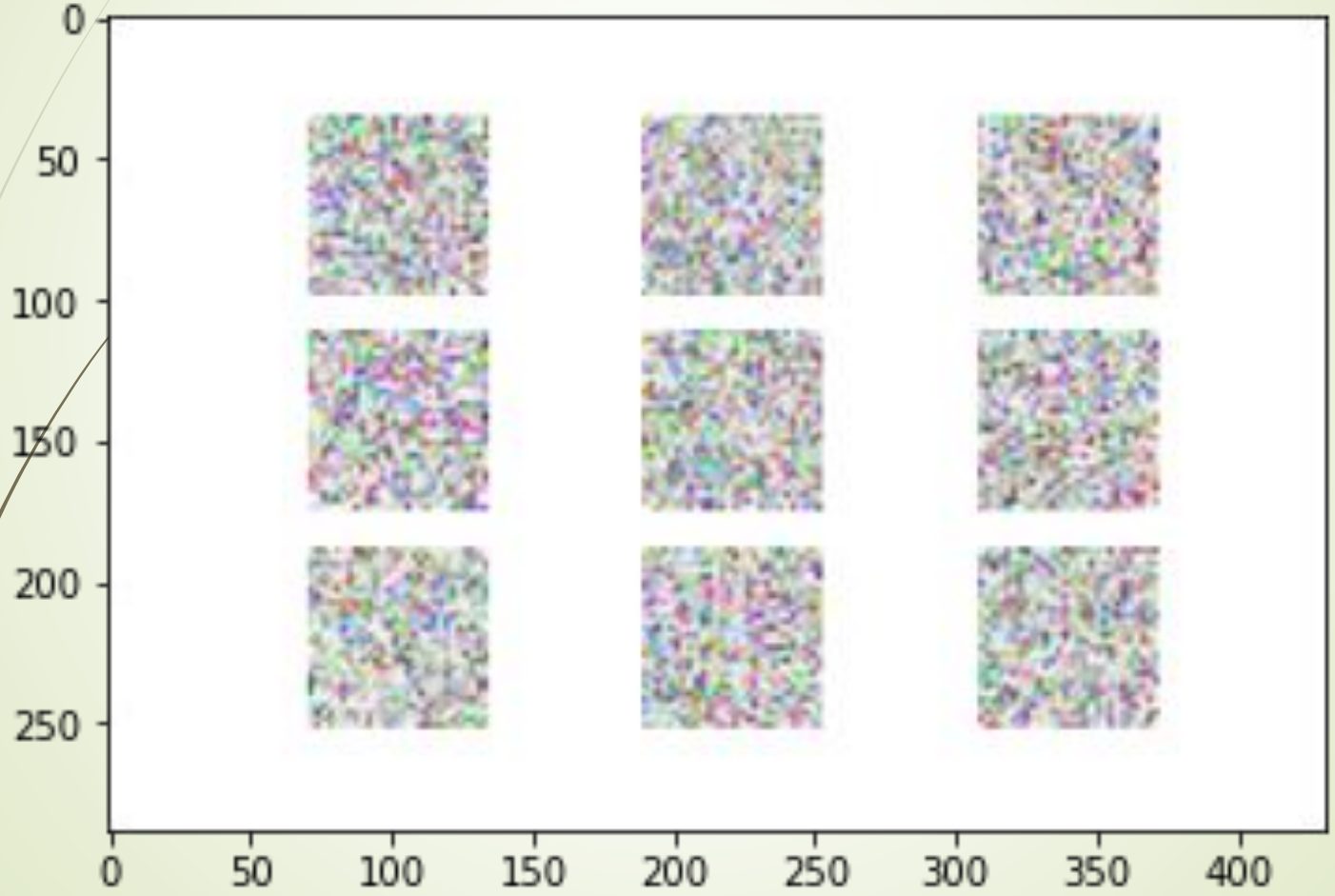
Synthetic Images

Beginning



Synthetic Images

Middle



Synthetic Images

End