

A Backdoor Detector for BadNets Trained on the YouTube Face Dataset using the Pruning Defense

Github link: https://github.com/superChoi7/ML_for_Cyber_Lab3

1. Prepare the BadNet model and dataset

```
In [ ]: import tensorflow as tf
import keras
import keras.backend as K
from keras import Model

import h5py
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
```

Mount the google drive. The working directory in my google drive is located at /content/drive/MyDrive/EL-GY-9163/lab3 .

```
In [ ]: # mount google drive
from google.colab import drive
drive.mount('/content/drive')
# change to the working dirctory
%cd /content/drive/MyDrive/EL-GY-9163/lab3
```

Drive already mounted at /content/drive; to attempt to forcibly remount, call drive.mount("/content/drive", force_remount=True).
/content/drive/.shortcut-targets-by-id/1DVXVgBaG-1YX7_2AmIi-DZ5gD-U0Z4O-/EL-GY-9163/lab3

1.1 Set up model

Import the BadNet model model_B from models/ folder.

```
In [ ]: modelPath = './models/bd_net.h5'
model_B = keras.models.load_model(modelPath)
model_B.summary()
```

Model: "model_1"

Layer (type)	Output Shape	Param #	Connected to
=====			
input (InputLayer)	[(None, 55, 47, 3)]	0	[]
conv_1 (Conv2D)	(None, 52, 44, 20)	980	['input[0][0]']
pool_1 (MaxPooling2D)	(None, 26, 22, 20)	0	['conv_1[0][0]']

conv_2 (Conv2D) [0]']	(None, 24, 20, 40)	7240	['pool_1[0]
pool_2 (MaxPooling2D) [0]']	(None, 12, 10, 40)	0	['conv_2[0]
conv_3 (Conv2D) [0]']	(None, 10, 8, 60)	21660	['pool_2[0]
pool_3 (MaxPooling2D) [0]']	(None, 5, 4, 60)	0	['conv_3[0]
conv_4 (Conv2D) [0]']	(None, 4, 3, 80)	19280	['pool_3[0]
flatten_1 (Flatten) [0]']	(None, 1200)	0	['pool_3[0]
flatten_2 (Flatten) [0]']	(None, 960)	0	['conv_4[0]
fc_1 (Dense) [0]']	(None, 160)	192160	['flatten_1[0]
fc_2 (Dense) [0]']	(None, 160)	153760	['flatten_2[0]
add_1 (Add)	(None, 160)	0	['fc_1[0][0]', 'fc_2[0][0]']
activation_1 (Activation)	(None, 160)	0	['add_1[0][0]']
output (Dense) [0][0]']	(None, 1283)	206563	['activation_1

=====

Total params: 601,643
Trainable params: 601,643
Non-trainable params: 0

Use `eval.py` script to output the accuracy.

```
In [ ]: !python eval.py data/cl/test.h5 data/bd/bd_test.h5 models/bd_net.h5
```

```
2021-12-11 19:43:37.741877: W tensorflow/core/common_runtime/gpu/gpu_bfc_allocat
or.cc:39] Overriding allow_growth setting because the TF_FORCE_GPU_ALLOW_GROWTH
environment variable is set. Original config value was 0.
Clean Classification accuracy: 98.62042088854248
Attack Success Rate: 100.0
```

1.2 Import dataset

Import dataset from `data/` folder.

```
In [ ]: def data_loader(filepath):
        """
        Load data
        """
```

```

data = h5py.File(filepath, 'r')
x_data = np.array(data['data'])
y_data = np.array(data['label'])
x_data = x_data.transpose((0,2,3,1))
return x_data, y_data

def get_accuracy_cl(bd_model, cl_x, cl_y):
    """
    Classification accuracy on clean dataset
    """
    cl_label_p = np.argmax(bd_model.predict(cl_x), axis=1)
    cl_acc = np.mean(np.equal(cl_label_p, cl_y))*100
    print('Clean Classification accuracy:', cl_acc)
    return cl_acc

def get_attack_rate_bd(bd_model, bd_x, bd_y):
    """
    Attack success rate
    """
    bd_label_p = np.argmax(bd_model.predict(bd_x), axis=1)
    asr = np.mean(np.equal(bd_label_p, bd_y))*100
    print('Attack Success Rate:', asr)
    return asr

```

```

In [ ]: # load dataset
cl_x_test, cl_y_test = data_loader('./data/cl/test.h5')
cl_x_valid, cl_y_valid = data_loader('./data/cl/valid.h5')
bd_x_test, bd_y_test = data_loader('./data/bd/bd_test.h5')
bd_x_valid, bd_y_valid = data_loader('./data/bd/bd_valid.h5')
N = len(set(cl_y_test))

```

```

In [ ]: print('cl_x_test.shape', cl_x_test.shape)
print('cl_x_valid.shape', cl_x_valid.shape)
print('bd_x_test.shape', bd_x_test.shape)
print('bd_x_valid.shape', bd_x_valid.shape)
print('number of labels: {}'.format(N))

```

```

cl_x_test.shape (12830, 55, 47, 3)
cl_x_valid.shape (11547, 55, 47, 3)
bd_x_test.shape (12830, 55, 47, 3)
bd_x_valid.shape (11547, 55, 47, 3)
number of labels: 1283

```

Plot some images to see differences between the clean dataset and the backdoored dataset.

```

In [ ]: def plot_images(row, col, images):
plt.figure(figsize=(col, row))
for i in range(1, row*col):
    plt.subplot(row, col, i)
    plt.axis('off')
    plt.imshow(images[i] / 255)

plot_images(1, 10, cl_x_test)
plot_images(1, 10, bd_x_test)

```



2. Repair the BadNet

Given a backdoored neural network classifier `model_B` and a validation dataset of clean data `cl_x_valid`, our primary objectives are:

- Prune neurons in increasing order of average activation values over the entire validation set to obtain the new network `model_B_prime`.
- Design a repaired BadNet `model_G`, which outputs the true label if the input is clean, otherwise outputs $N + 1$ where N is the number of correct classes.

Requirements in lab3 are as follows and the strategy to handle each is given accordingly:

1. *Prune the last pooling layer of BadNet `model_B` by removing one channel at a time from that layer.*

From the output of `model_B.summary()`, we can see that the layer just before the FC layers is `conv_3`. Therefore, we select the `conv_3` layer to perform the pruning process. The pruning method is setting all weights and biases to 0.

2. *Channels should be removed in increasing order of average activation values over the entire validation set.*

First, we compute the average activation values of each channels in the `conv_3` layer. Then, sort them in increasing order. Finally, prune the channels by the index order.

3. *You will stop pruning once the validation accuracy drops atleast $X\%$ below the original accuracy. This will be your new network `model_B_prime`.*

We need to obtain three `model_B_prime` for $X = \{2\%, 4\%, 10\%\}$. And evaluate the performance of each of them.

2.1 compute average activation values and sort them in order

```
In [ ]: model_B_prime = keras.models.load_model(modelPath)
conv_3_layer = Model(inputs=model_B_prime.input, outputs=model_B_prime.get_layer(

cl_output = np.mean(conv_3_layer.predict(cl_x_valid), axis=0) # average activation
idx_cl = np.argsort(np.sum(cl_output, axis=(0, 1))) # sort in increasing order b
print('pruning order:', idx_cl)
print('sum of values:', np.sort(np.sum(cl_output, axis=(0, 1))))

pruning order: [ 0 26 27 30 31 33 34 36 37 38 25 39 41 44 45 47 48 49 50 53 55 4
0 24 59
          9  2 12 13 17 14 15 23  6 51 32 22 21 20 19 43  3 58 42  1 29 16  5 56
```

```

8 11 46 54 10 4 18 7 28 35 52 57]
sum of values: [0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00 0.000000
0e+00
0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00
0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00
0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00
0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00
0.0000000e+00 8.1761241e-02 1.7022049e-01 3.4326324e-01 3.5326570e-01
1.1469307e+00 2.5636518e+00 5.0632777e+00 8.5227070e+00 1.2338528e+01
1.7449804e+01 1.7924015e+01 2.1239485e+01 2.2799480e+01 3.7998375e+01
5.7887745e+01 6.9720184e+01 7.0036171e+01 7.1875938e+01 8.5014481e+01
8.7924690e+01 1.6558408e+02 1.9046291e+02 2.2774966e+02 2.3424629e+02
2.3575995e+02 2.4531390e+02 2.8121811e+02 3.2685696e+02 3.9856320e+02]

```

2.2 Prune the channel by order and plot the accuracy and on the clean validation dataset

```

In [ ]: model_B_prime = keras.models.load_model(modelPath)
layer = model_B_prime.get_layer('conv_3')
weight, bias = layer.get_weights()

iter = 0
acc_cl = []
print('original accuracy')
acc_cl.append(get_accuracy_cl(model_B_prime, cl_x_valid, cl_y_valid))

for i in idx_cl:
    weight[:, :, :, i] = 0
    bias[i] = 0
    layer.set_weights([weight, bias])
    iter += 1
    print('iteration ', iter)
    acc_cl.append(get_accuracy_cl(model_B_prime, cl_x_valid, cl_y_valid))

```

```

original accuracy
Clean Classification accuracy: 98.64899974019225
iteration 1
Clean Classification accuracy: 98.64899974019225
iteration 2
Clean Classification accuracy: 98.64899974019225
iteration 3
Clean Classification accuracy: 98.64899974019225
iteration 4
Clean Classification accuracy: 98.64899974019225
iteration 5
Clean Classification accuracy: 98.64899974019225
iteration 6
Clean Classification accuracy: 98.64899974019225
iteration 7
Clean Classification accuracy: 98.64899974019225
iteration 8
Clean Classification accuracy: 98.64899974019225
iteration 9
Clean Classification accuracy: 98.64899974019225
iteration 10
Clean Classification accuracy: 98.64899974019225
iteration 11
Clean Classification accuracy: 98.64899974019225
iteration 12
Clean Classification accuracy: 98.64899974019225
iteration 13

```

Clean Classification accuracy: 98.64899974019225
iteration 14
Clean Classification accuracy: 98.64899974019225
iteration 15
Clean Classification accuracy: 98.64899974019225
iteration 16
Clean Classification accuracy: 98.64899974019225
iteration 17
Clean Classification accuracy: 98.64899974019225
iteration 18
Clean Classification accuracy: 98.64899974019225
iteration 19
Clean Classification accuracy: 98.64899974019225
iteration 20
Clean Classification accuracy: 98.64899974019225
iteration 21
Clean Classification accuracy: 98.64899974019225
iteration 22
Clean Classification accuracy: 98.64899974019225
iteration 23
Clean Classification accuracy: 98.64899974019225
iteration 24
Clean Classification accuracy: 98.64899974019225
iteration 25
Clean Classification accuracy: 98.64899974019225
iteration 26
Clean Classification accuracy: 98.64899974019225
iteration 27
Clean Classification accuracy: 98.64899974019225
iteration 28
Clean Classification accuracy: 98.64899974019225
iteration 29
Clean Classification accuracy: 98.64899974019225
iteration 30
Clean Classification accuracy: 98.64899974019225
iteration 31
Clean Classification accuracy: 98.64899974019225
iteration 32
Clean Classification accuracy: 98.64899974019225
iteration 33
Clean Classification accuracy: 98.64899974019225
iteration 34
Clean Classification accuracy: 98.64033948211657
iteration 35
Clean Classification accuracy: 98.64033948211657
iteration 36
Clean Classification accuracy: 98.63167922404088
iteration 37
Clean Classification accuracy: 98.65765999826795
iteration 38
Clean Classification accuracy: 98.64899974019225
iteration 39
Clean Classification accuracy: 98.6056984498138
iteration 40
Clean Classification accuracy: 98.57105741751104
iteration 41
Clean Classification accuracy: 98.25062786871048
iteration 42
Clean Classification accuracy: 98.19000606218066
iteration 43
Clean Classification accuracy: 97.65307006148784
iteration 44
Clean Classification accuracy: 97.50584567420108
iteration 45
Clean Classification accuracy: 95.75647354291158

```

iteration 46
Clean Classification accuracy: 95.20221702606739
iteration 47
Clean Classification accuracy: 94.77786438035854
iteration 48
Clean Classification accuracy: 94.344851476574
iteration 49
Clean Classification accuracy: 93.85121676625964
iteration 50
Clean Classification accuracy: 92.16246644149996
iteration 51
Clean Classification accuracy: 89.17467740538669
iteration 52
Clean Classification accuracy: 84.43751623798389
iteration 53
Clean Classification accuracy: 76.48739932449988
iteration 54
Clean Classification accuracy: 45.6915216073439
iteration 55
Clean Classification accuracy: 28.15449900407032
iteration 56
Clean Classification accuracy: 13.795791114575215
iteration 57
Clean Classification accuracy: 5.81103316878843
iteration 58
Clean Classification accuracy: 1.5501861955486274
iteration 59
Clean Classification accuracy: 0.7188014202823244
iteration 60
Clean Classification accuracy: 0.0779423226812159

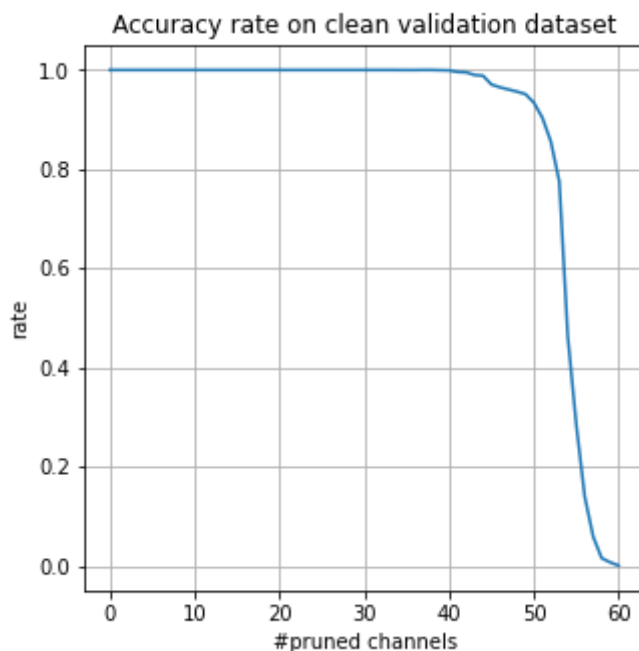
```

In []:

```

# plot the accuracy
plt.figure(figsize=(5, 5))
plt.plot(range(len(acc_cl)), acc_cl / acc_cl[0])
plt.xlabel('#pruned channels')
plt.ylabel('rate')
plt.title('Accuracy rate on clean validation dataset')
plt.grid('on')

```



3. Results and evaluation

3.1 Repair networks for different X

From the plot above, we select to prune 46, 49, 52 channels for X = 2%, 4%, 10%, respectively.

```
In [ ]: # X = 2%
model_B_prime_2 = keras.models.load_model(modelPath)
layer = model_B_prime_2.get_layer('conv_3')
weight, bias = layer.get_weights()

iter = 0
acc_cl = []
print('original accuracy')
acc_cl.append(get_accuracy_cl(model_B_prime_2, cl_x_valid, cl_y_valid))

for i in idx_cl:
    weight[:, :, :, i] = 0
    bias[i] = 0
    layer.set_weights([weight, bias])
    iter += 1
    if iter == 45:
        break

print('accuracy after pruning {} channels'.format(iter))
acc_cl.append(get_accuracy_cl(model_B_prime_2, cl_x_valid, cl_y_valid))
print('accuracy drop: {:.4f}%'.format((acc_cl[0] - acc_cl[-1]) / acc_cl[0] * 100))

model_B_prime_2.save('/content/drive/MyDrive/EL-GY-9163/lab3/models/repaired_2.h5')

original accuracy
Clean Classification accuracy: 98.64899974019225
accuracy after pruning 45 channels
Clean Classification accuracy: 95.75647354291158
accuracy drop: 2.9321%

/usr/local/lib/python3.7/dist-packages/keras/engine/functional.py:1410: CustomMa
skWarning: Custom mask layers require a config and must override get_config. Whe
n loading, the custom mask layer must be passed to the custom_objects argument.
  layer_config = serialize_layer_fn(layer)
```

```
In [ ]: # evaluation X = 2%
!python eval.py data/cl/test.h5 data/bd/bd_test.h5 models/repaired_2.h5

2021-12-11 20:23:51.323020: W tensorflow/core/common_runtime/gpu/gpu_bfc_allocat
or.cc:39] Overriding allow_growth setting because the TF_FORCE_GPU_ALLOW_GROWTH
environment variable is set. Original config value was 0.
2021-12-11 20:23:52.097072: W tensorflow/core/framework/cpu_allocator_impl.cc:8
2] Allocation of 397986600 exceeds 10% of free system memory.
2021-12-11 20:24:12.364632: W tensorflow/core/framework/cpu_allocator_impl.cc:8
2] Allocation of 65843560 exceeds 10% of free system memory.
Clean Classification accuracy: 95.90023382696803
2021-12-11 20:24:13.721110: W tensorflow/core/framework/cpu_allocator_impl.cc:8
2] Allocation of 397986600 exceeds 10% of free system memory.
2021-12-11 20:24:15.426476: W tensorflow/core/framework/cpu_allocator_impl.cc:8
2] Allocation of 65843560 exceeds 10% of free system memory.
Attack Success Rate: 100.0
```



```
In [ ]: # X = 4%
model_B_prime_4 = keras.models.load_model(modelPath)
layer = model_B_prime_4.get_layer('conv_3')
weight, bias = layer.get_weights()

iter = 0
acc_cl = []
print('original accuracy')
acc_cl.append(get_accuracy_cl(model_B_prime_4, cl_x_valid, cl_y_valid))

for i in idx_cl:
    weight[:, :, :, i] = 0
    bias[i] = 0
    layer.set_weights([weight, bias])
    iter += 1
    if iter == 48:
        break

print('accuracy after pruning {} channels'.format(iter))
acc_cl.append(get_accuracy_cl(model_B_prime_4, cl_x_valid, cl_y_valid))
print('accuracy drop: {:.4f}%'.format((acc_cl[0] - acc_cl[-1]) / acc_cl[0] * 100))

model_B_prime_4.save('/content/drive/MyDrive/EL-GY-9163/lab3/models/repaired_4.h5')
```

```
original accuracy
Clean Classification accuracy: 98.64899974019225
accuracy after pruning 48 channels
Clean Classification accuracy: 94.344851476574
accuracy drop: 4.3631%

/usr/local/lib/python3.7/dist-packages/keras/engine/functional.py:1410: CustomMa
skWarning: Custom mask layers require a config and must override get_config. Whe
n loading, the custom mask layer must be passed to the custom_objects argument.
    layer_config = serialize_layer_fn(layer)
```

```
In [ ]: # evaluation X = 4%
!python eval.py data/cl/test.h5 data/bd/bd_test.h5 models/repaired_4.h5
```

```
2021-12-11 20:24:46.935779: W tensorflow/core/common_runtime/gpu/gpu_bfc_allocat
or.cc:39] Overriding allow_growth setting because the TF_FORCE_GPU_ALLOW_GROWTH
environment variable is set. Original config value was 0.
2021-12-11 20:24:49.166729: W tensorflow/core/framework/cpu_allocator_impl.cc:8
2] Allocation of 397986600 exceeds 10% of free system memory.
Clean Classification accuracy: 94.77007014809041
2021-12-11 20:24:52.514484: W tensorflow/core/framework/cpu_allocator_impl.cc:8
2] Allocation of 397986600 exceeds 10% of free system memory.
Attack Success Rate: 99.98441153546376
```

```
In [ ]: # X = 10%
model_B_prime_10 = keras.models.load_model(modelPath)
layer = model_B_prime_10.get_layer('conv_3')
weight, bias = layer.get_weights()

iter = 0
acc_cl = []
print('original accuracy')
acc_cl.append(get_accuracy_cl(model_B_prime_10, cl_x_valid, cl_y_valid))

for i in idx_cl:
```

```

weight[:, :, :, i] = 0
bias[i] = 0
layer.set_weights([weight, bias])
iter += 1
if iter == 52:
    break
print('accuracy after pruning {} channels'.format(iter))
acc_cl.append(get_accuracy_cl(model_B_prime_10, cl_x_valid, cl_y_valid))
print('accuracy drop: {:.4f}%'.format((acc_cl[0] - acc_cl[-1]) / acc_cl[0] * 100))

model_B_prime_10.save('/content/drive/MyDrive/EL-GY-9163/lab3/models/repaired_10

```

```

original accuracy
Clean Classification accuracy: 98.64899974019225
accuracy after pruning 52 channels
Clean Classification accuracy: 84.43751623798389
accuracy drop: 14.4061%

/usr/local/lib/python3.7/dist-packages/keras/engine/functional.py:1410: CustomMa
skWarning: Custom mask layers require a config and must override get_config. Whe
n loading, the custom mask layer must be passed to the custom_objects argument.
    layer_config = serialize_layer_fn(layer)

```

```

In [ ]: # evaluation X = 10%
!python eval.py data/cl/test.h5 data/bd/bd_test.h5 models/repaired_10.h5

```

```

2021-12-11 20:25:13.642781: W tensorflow/core/common_runtime/gpu/gpu_bfc_allocat
or.cc:39] Overriding allow_growth setting because the TF_FORCE_GPU_ALLOW_GROWTH
environment variable is set. Original config value was 0.
2021-12-11 20:25:16.373720: W tensorflow/core/framework/cpu_allocator_impl.cc:8
2] Allocation of 397986600 exceeds 10% of free system memory.
Clean Classification accuracy: 84.54403741231489
2021-12-11 20:25:19.698580: W tensorflow/core/framework/cpu_allocator_impl.cc:8
2] Allocation of 397986600 exceeds 10% of free system memory.
Attack Success Rate: 77.20966484801247

```

Construct GoodNet and output the accuracy on clean test dataset and the attack success rate.

```

In [ ]: def Good_Net(model_B, model_B_prime, data, N=N):
        """
        GoodNet
        """
        x = data
        y_pred_B = np.argmax(model_B.predict(x), axis=1)
        y_pred_B_prime = np.argmax(model_B_prime.predict(x), axis=1)

        y_hat = [y_pred_B[i] if y_pred_B[i] == y_pred_B_prime[i] else N + 1 for i in
        return y_hat

y_pred_2 = Good_Net(model_B, model_B_prime_2, cl_x_test)
y_pred_4 = Good_Net(model_B, model_B_prime_4, cl_x_test)
y_pred_10 = Good_Net(model_B, model_B_prime_10, cl_x_test)
print('Clean Classification accuracy')
print('GoodNet_2: {:.4f}%'.format(np.mean(np.equal(y_pred_2, cl_y_test)) * 100))
print('GoodNet_4: {:.4f}%'.format(np.mean(np.equal(y_pred_4, cl_y_test)) * 100))
print('GoodNet_10: {:.4f}%'.format(np.mean(np.equal(y_pred_10, cl_y_test)) * 100))

y_pred_2 = Good_Net(model_B, model_B_prime_2, bd_x_test)
y_pred_4 = Good_Net(model_B, model_B_prime_4, bd_x_test)
y_pred_10 = Good_Net(model_B, model_B_prime_10, bd_x_test)
print('Attack Success Rate')

```

```
print('GoodNet_2: {:.4f}%'.format(np.mean(np.equal(y_pred_2, bd_y_test)) * 100))
print('GoodNet_4: {:.4f}%'.format(np.mean(np.equal(y_pred_4, bd_y_test)) * 100))
print('GoodNet_10: {:.4f}%'.format(np.mean(np.equal(y_pred_10, bd_y_test)) * 100))
```

Clean Classification accuracy

GoodNet_2: 95.7443%

GoodNet_4: 94.5752%

GoodNet_10: 84.3336%

Attack Success Rate

GoodNet_2: 100.0000%

GoodNet_4: 99.9844%

GoodNet_10: 77.2097%

3.2 Plot the accuracy on clean test data and the attack success rate vs the fraction of channels pruned

Because of the limited computing source of colab, it always get crushed for limited RAM when calculating the accuracy and attack succeed rate simultaneously. From the results in section 2.2, we believe it is safe to directly prune the first 35 channels and assume the accuracy and the attack succeed rate are both maintained.

In []:

```
# save the outputs in each iteration using clean test dataset
model_B_prime = keras.models.load_model(modelPath)
layer = model_B_prime.get_layer('conv_3')
weight, bias = layer.get_weights()

iter = 0
acc_cl = []
asr_bd = []
iters = []
print('original accuracy')
acc_cl.append(get_accuracy_cl(model_B_prime, cl_x_test, cl_y_test))
asr_bd.append(get_attack_rate_bd(model_B_prime, bd_x_test, bd_y_test))
iters.append(iter)

for i in idx_cl:
    weight[:, :, :, i] = 0
    bias[i] = 0
    layer.set_weights([weight, bias])
    iter += 1
    if iter <= 35:
        continue
    print('iteration ', iter)
    acc_cl.append(get_accuracy_cl(model_B_prime, cl_x_test, cl_y_test))
    asr_bd.append(get_attack_rate_bd(model_B_prime, bd_x_test, bd_y_test))
    iters.append(iter)
```

original accuracy

Clean Classification accuracy: 98.62042088854248

Attack Success Rate: 100.0

iteration 36

Clean Classification accuracy: 98.60483242400623

Attack Success Rate: 100.0

iteration 37

Clean Classification accuracy: 98.60483242400623

Attack Success Rate: 100.0

iteration 38

Clean Classification accuracy: 98.58924395947

Attack Success Rate: 100.0

iteration 39
Clean Classification accuracy: 98.55027279812938
Attack Success Rate: 100.0
iteration 40
Clean Classification accuracy: 98.53468433359313
Attack Success Rate: 100.0
iteration 41
Clean Classification accuracy: 98.28526890101324
Attack Success Rate: 100.0
iteration 42
Clean Classification accuracy: 98.269680436477
Attack Success Rate: 100.0
iteration 43
Clean Classification accuracy: 97.88776305533905
Attack Success Rate: 100.0
iteration 44
Clean Classification accuracy: 97.66173031956352
Attack Success Rate: 100.0
iteration 45
Clean Classification accuracy: 95.90023382696803
Attack Success Rate: 100.0
iteration 46
Clean Classification accuracy: 95.5261106780982
Attack Success Rate: 99.97661730319564
iteration 47
Clean Classification accuracy: 95.22213561964146
Attack Success Rate: 99.97661730319564
iteration 48
Clean Classification accuracy: 94.77007014809041
Attack Success Rate: 99.98441153546376
iteration 49
Clean Classification accuracy: 94.17770849571318
Attack Success Rate: 99.97661730319564
iteration 50
Clean Classification accuracy: 92.50974279033515
Attack Success Rate: 80.576773187841
iteration 51
Clean Classification accuracy: 89.84411535463757
Attack Success Rate: 80.6469212782541
iteration 52
Clean Classification accuracy: 84.54403741231489
Attack Success Rate: 77.20966484801247
iteration 53
Clean Classification accuracy: 76.30553390491036
Attack Success Rate: 36.26656274356976
iteration 54
Clean Classification accuracy: 44.67653936087295
Attack Success Rate: 16.03273577552611
iteration 55
Clean Classification accuracy: 27.918939984411534
Attack Success Rate: 3.72564302416212
iteration 56
Clean Classification accuracy: 13.834762275915821
Attack Success Rate: 16.399064692127826
iteration 57
Clean Classification accuracy: 5.728760717069369
Attack Success Rate: 0.303975058456742
iteration 58
Clean Classification accuracy: 1.5198752922837102
Attack Success Rate: 0.0
iteration 59
Clean Classification accuracy: 0.646921278254092
Attack Success Rate: 0.0
iteration 60

Clean Classification accuracy: 0.0779423226812159
Attack Success Rate: 0.0

Plot the accuracy on clean test data and the attack success rate vs the fraction of channels pruned.

```
In [ ]: # plot the results
fraction = np.array(iters) / iters[-1]

plt.figure(figsize=(5, 5))
plt.plot(fraction, acc_cl / acc_cl[0], label='accuracy')
plt.plot(fraction, asr_bd / asr_bd[0], label='attack succeed rate')
plt.xlabel('fraction of channels')
plt.ylabel('rate')
plt.title('Rate on clean test dataset')
plt.legend()
plt.grid()
```

