Implementing convolutional neural networks

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14X14X64
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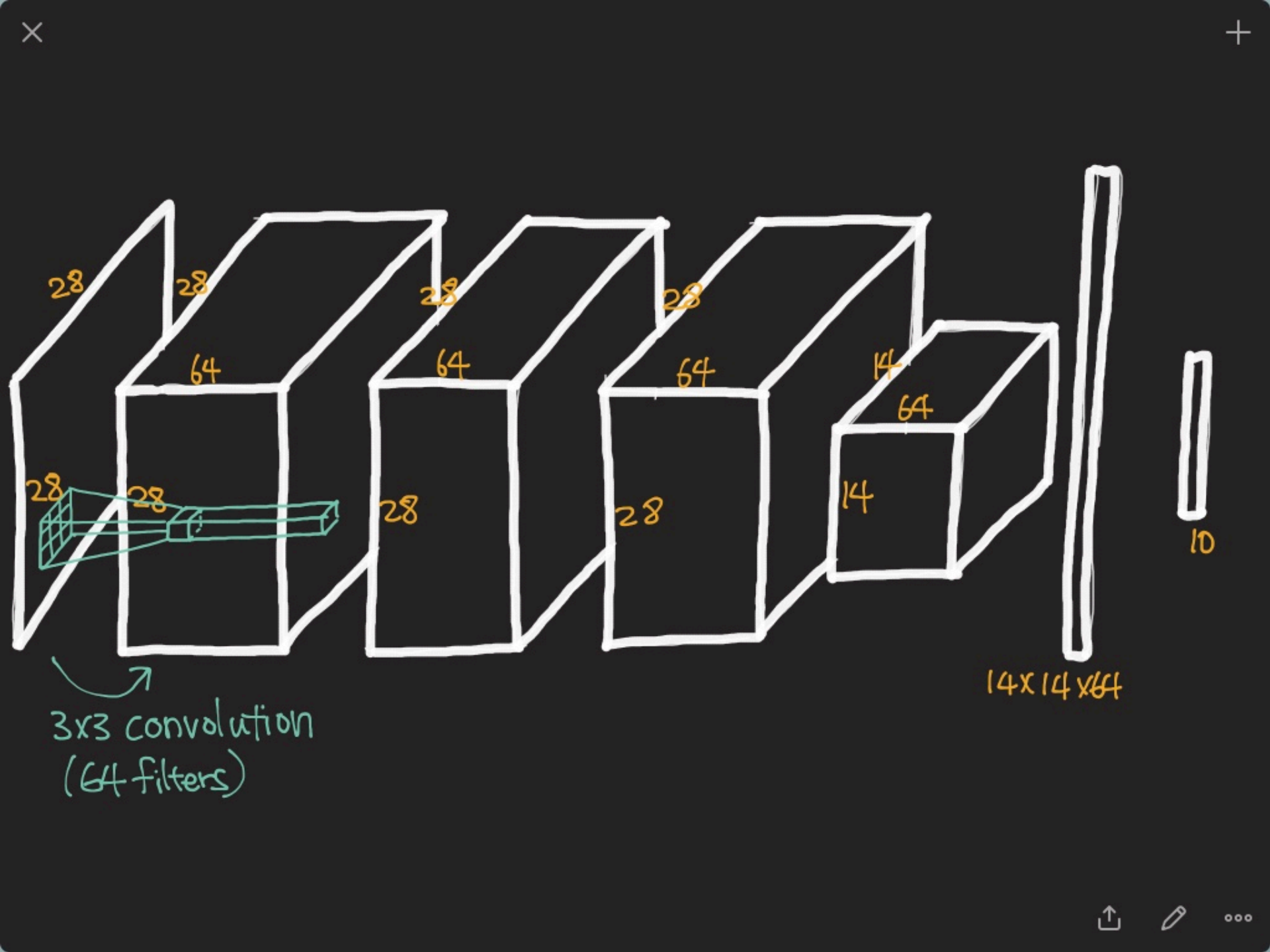
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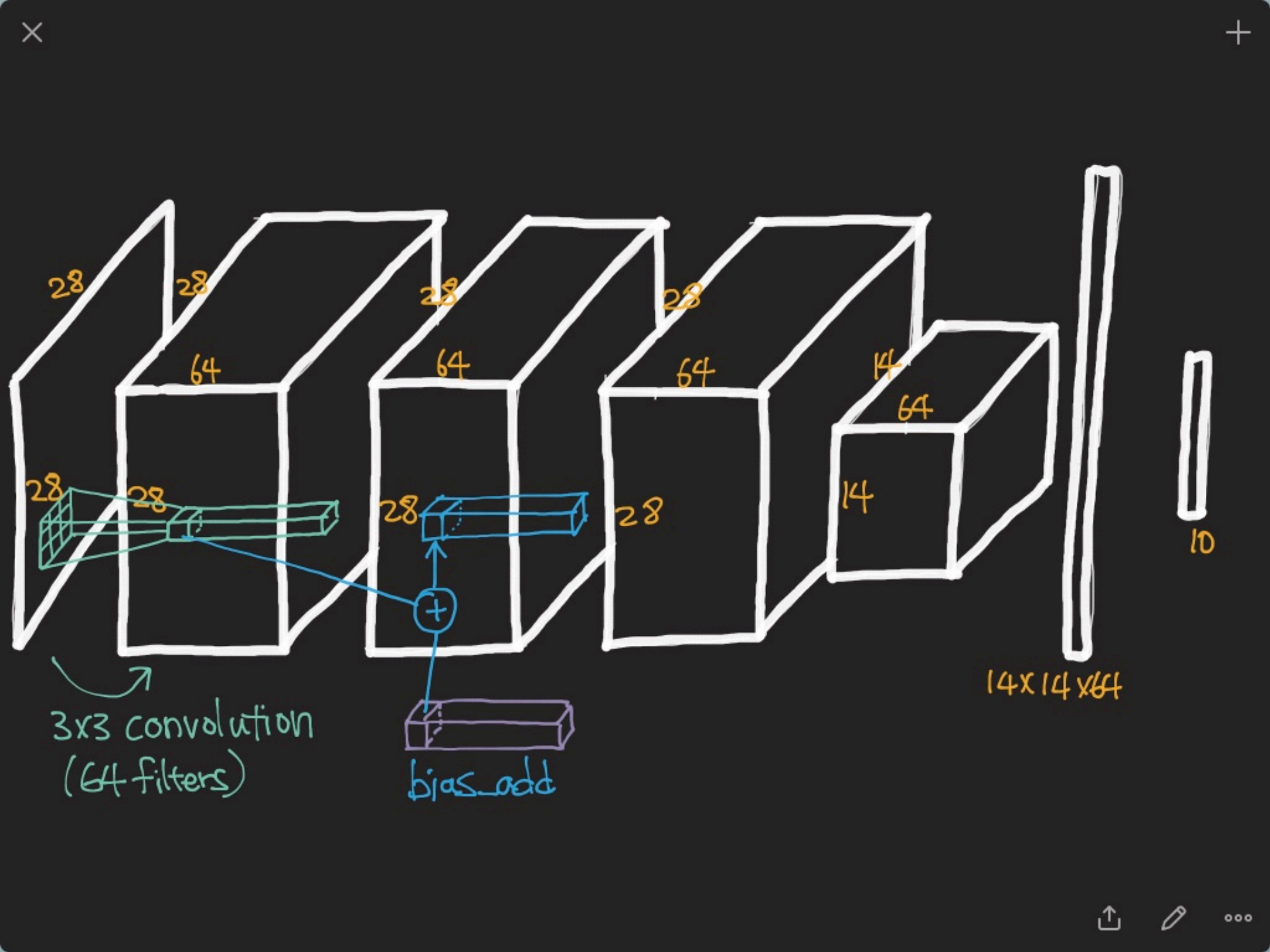
14x14x64
3x3 convolution
(64 filters)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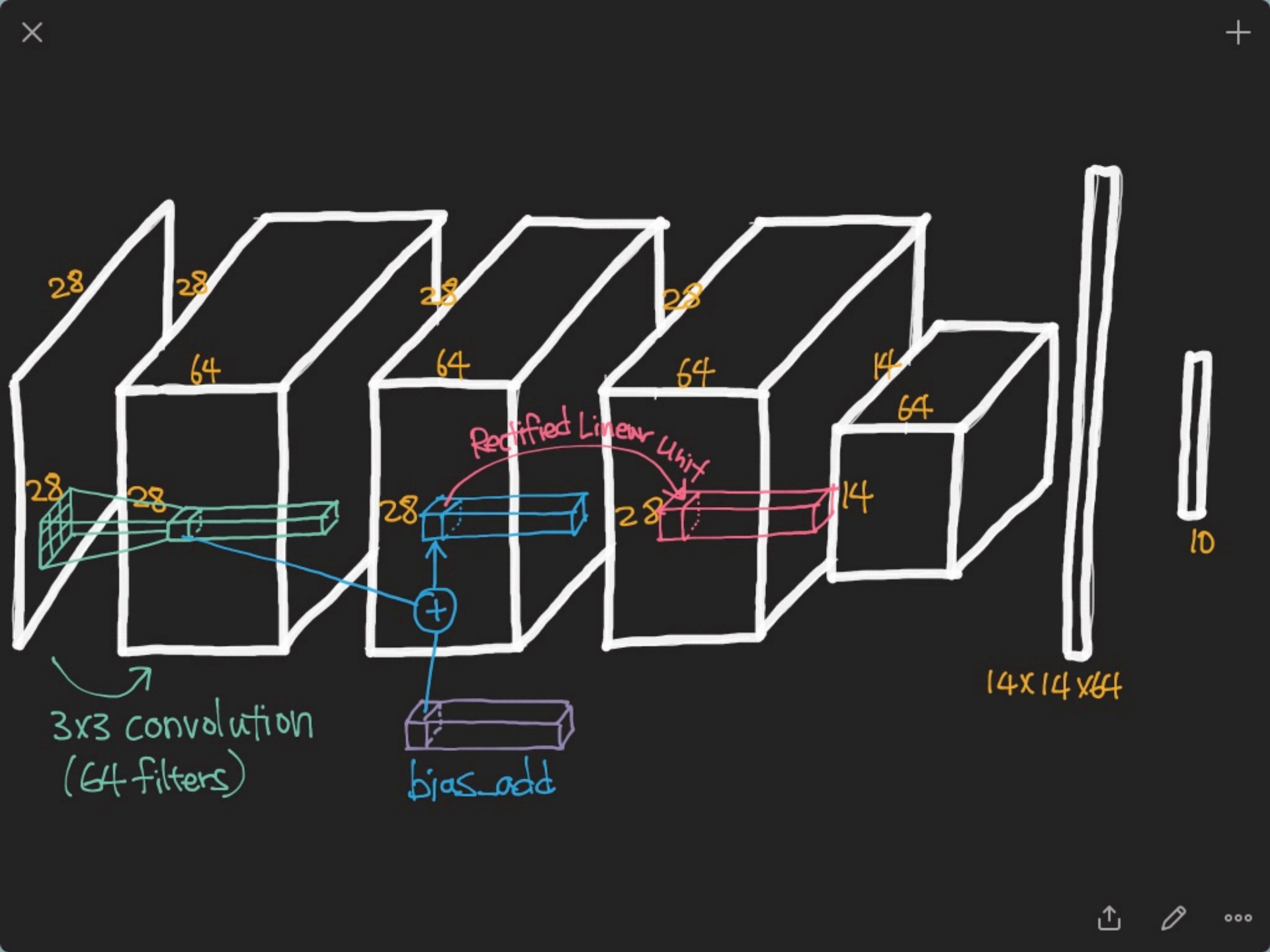
14X14X64
3x3 convolution
(64 filters)
bias_add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14
64
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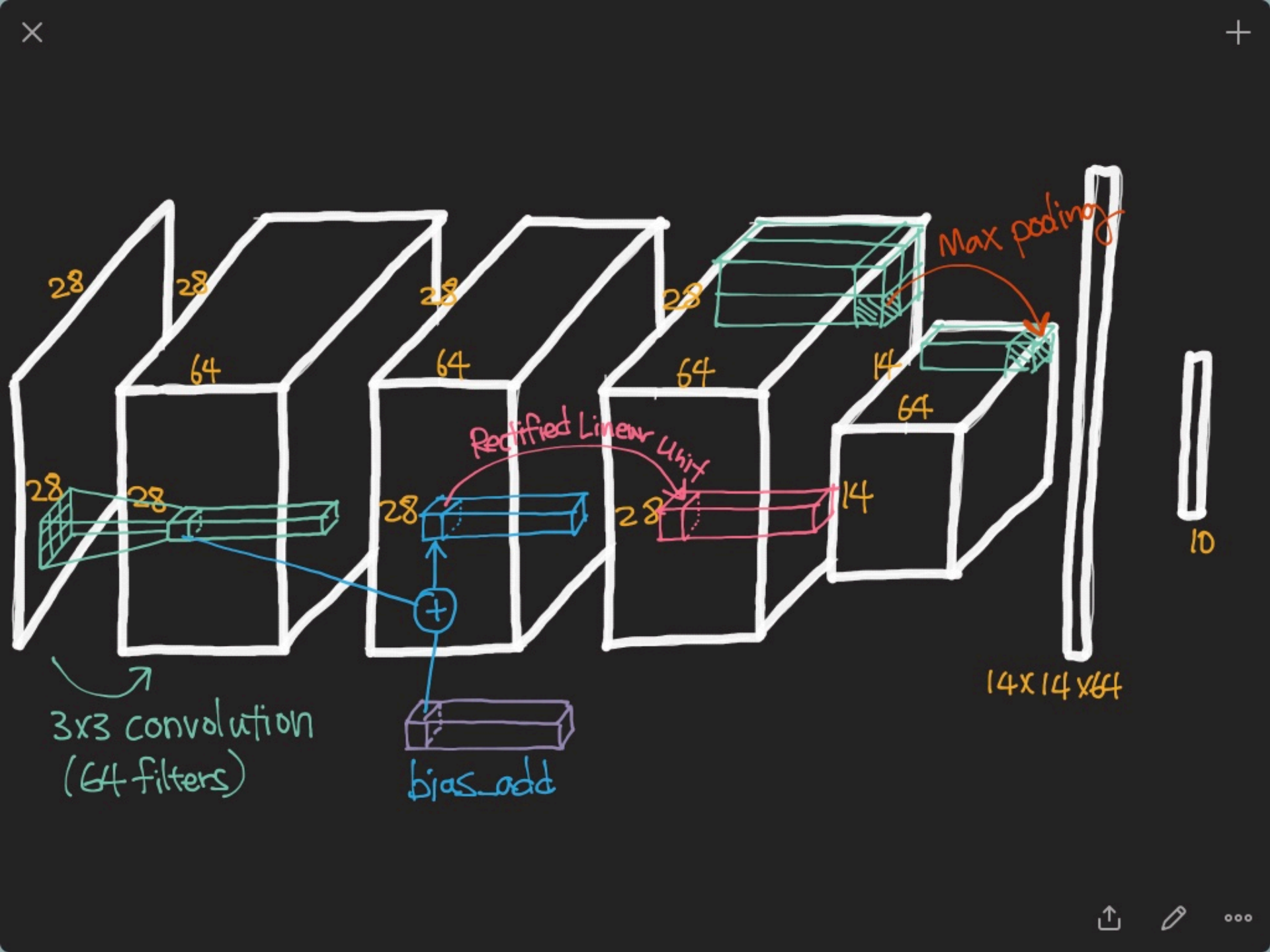
28
28
14
Rectified Linear Unit
10
14x14x64
3x3 convolution
(64 filters)
bias_add


28
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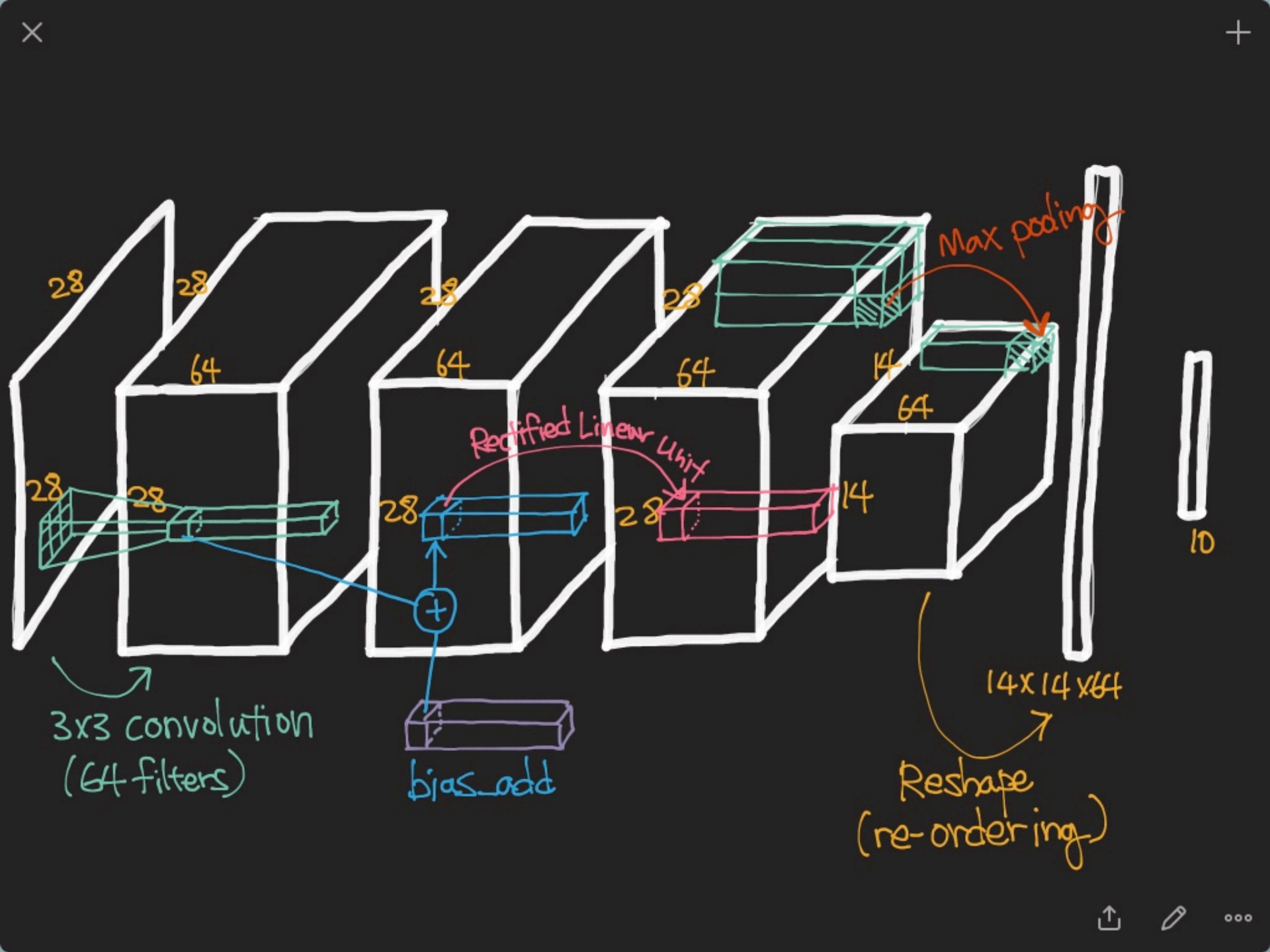
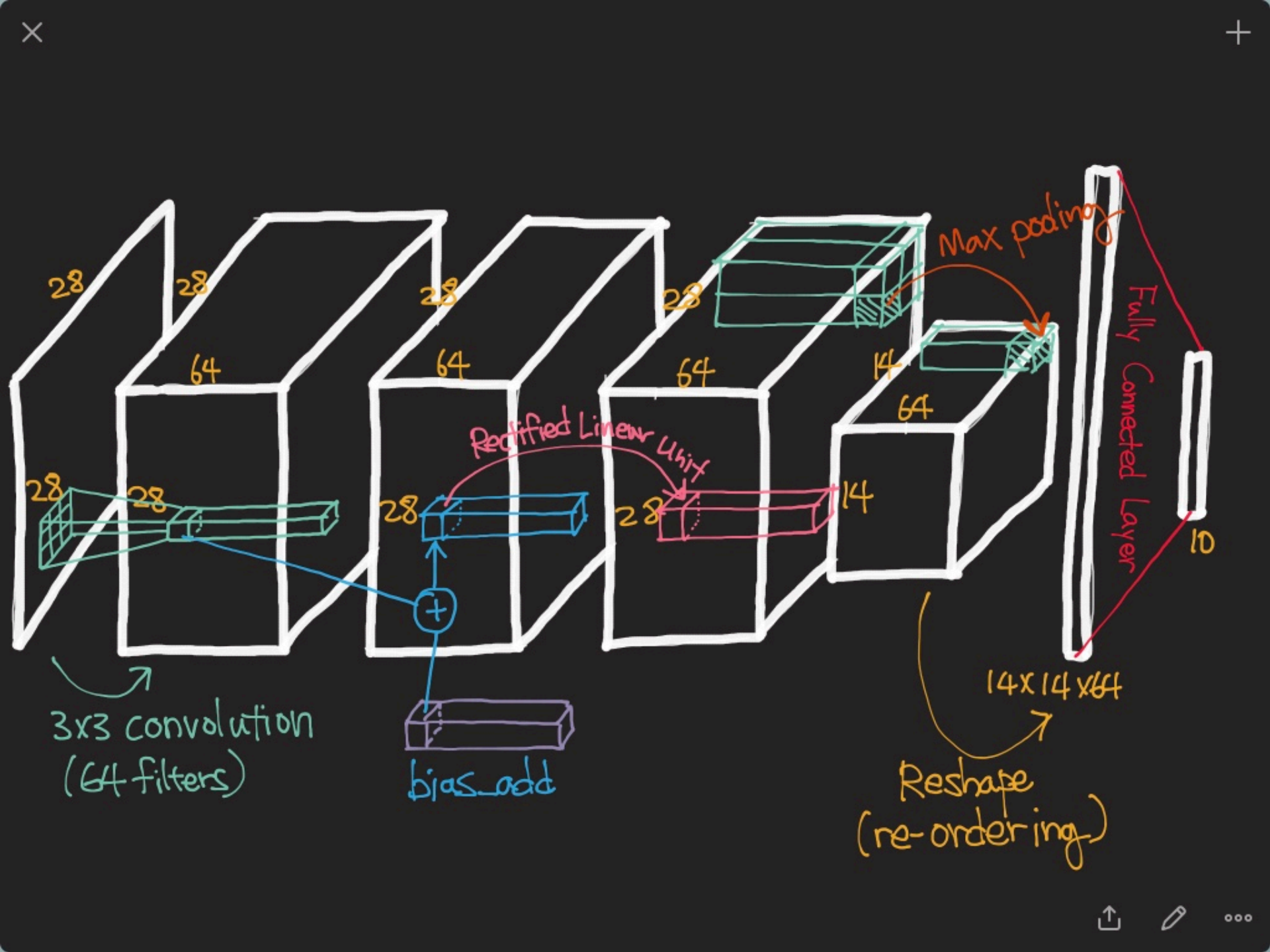
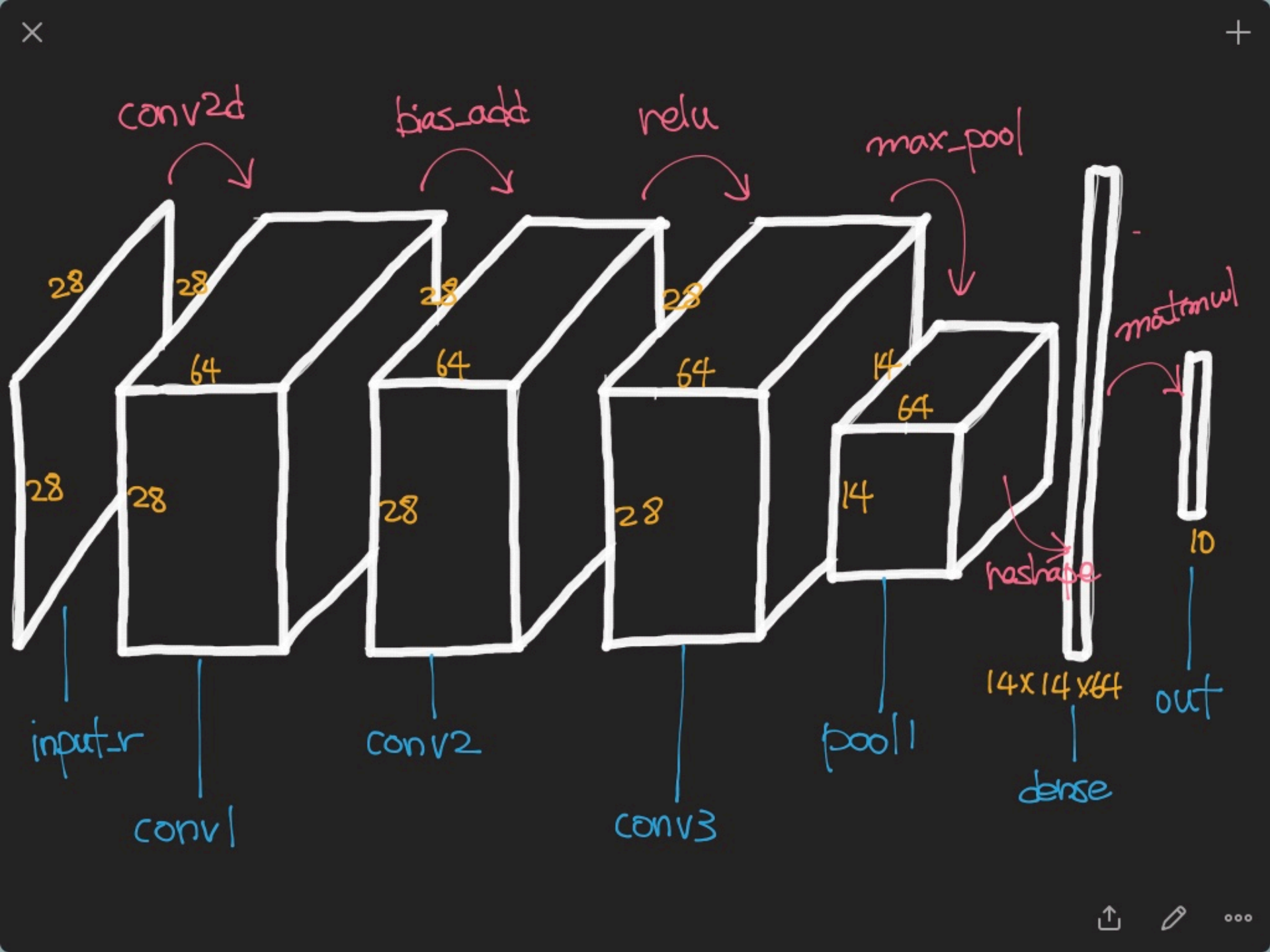
14
64
Max pooling
Rectified Linear Unit
28
28
28
28
14
10
3x3 convolution
(64 filters)
bias_add
14x14x64


28
28
64
28
28
64
28
28
64
14
14
64
Max pooling
Rectified Linear Unit
28
28
28
28
14
10
3x3 convolution
(64 filters)
bias_add
14x14x64
Reshape
(re-ordering)


28
28
64
28
28
64
28
28
64
14
14
64
Max pooling
Fully Connected Layer
10
Rectified Linear Unit
28
28
28
28
14
14x14x64
3x3 convolution
(64 filters)
bias_add
Reshape
(re-ordering)


conv2d
bias_add
relu
max_pool
matmul
28
28
64
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28
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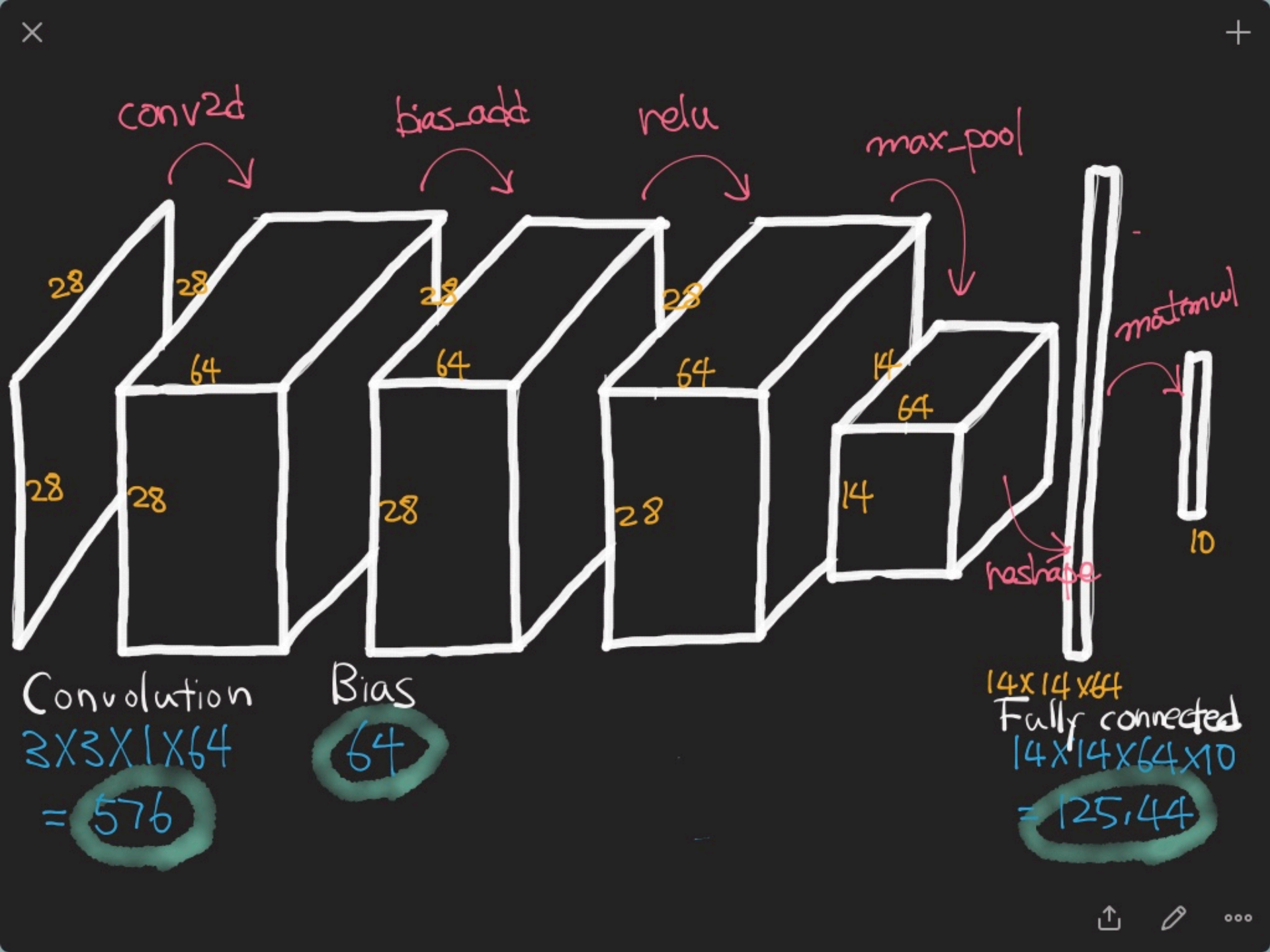
28
28
64
14
14
64
10
reshape
input_r
conv1
conv2
conv3
pool1
14x14x64
dense
out


conv2d
bias_add
relu
max_pool
matmul
28
28
64
28
28
28
28
64
28
28
64
14
14
64
14
10
reshape
Convolution
3X3X1X64
= 576
Bias
64
14X14X64
Fully connected
14X14X64X10
= 125,44

Implementing simple CNNs

SIMPLE CONVOLUTIONAL NEURAL NETWORK

```
import numpy as np
import tensorflow as tf
import matplotlib.pyplot as plt
from tensorflow.examples.tutorials.mnist import input_data
%matplotlib inline
print ("PACKAGES LOADED")
```

```
PACKAGES LOADED
```

LOAD MNIST

```
mnist = input_data.read_data_sets('data/', one_hot=True)
trainimg   = mnist.train.images
trainlabel = mnist.train.labels
testimg    = mnist.test.images
testlabel  = mnist.test.labels
print ("MNIST ready")
```

```
Extracting data/train-images-idx3-ubyte.gz
Extracting data/train-labels-idx1-ubyte.gz
Extracting data/t10k-images-idx3-ubyte.gz
Extracting data/t10k-labels-idx1-ubyte.gz
MNIST ready
```

SELECT DEVICE TO BE USED

```
device_type = "/cpu:0"
```

DEFINE CNN

```
with tf.device('/cpu:0'): # <= This is optional
    n_input  = 784
    n_output = 10
    weights  = {
        'wc1': tf.Variable(tf.random_normal([3, 3, 1, 64], stddev=0.1)),
        'wd1': tf.Variable(tf.random_normal([14*14*64, n_output], stddev=0.1))
    }
    biases   = {
        'bc1': tf.Variable(tf.random_normal([64], stddev=0.1)),
        'bd1': tf.Variable(tf.random_normal([n_output], stddev=0.1))
    }
    def conv_simple(_input, _w, _b):
        # Reshape input
        _input_r = tf.reshape(_input, shape=[-1, 28, 28, 1])
        # Convolution
        _conv1 = tf.nn.conv2d(_input_r, _w['wc1'], strides=[1, 1, 1, 1], padding='SAME')
        # Add-bias
        _conv2 = tf.nn.bias_add(_conv1, _b['bc1'])
        # Pass ReLu
        _conv3 = tf.nn.relu(_conv2)
        # Max-pooling
        _pool  = tf.nn.max_pool(_conv3, ksize=[1, 2, 2, 1], strides=[1, 2, 2, 1], padding='SAME')
        # Vectorize
        _dense = tf.reshape(_pool, [-1, _w['wd1'].get_shape().as_list()[0]])
        # Fully-connected layer
        _out = tf.add(tf.matmul(_dense, _w['wd1']), _b['bd1'])
        # Return everything
        out = {
            'input_r': _input_r, 'conv1': _conv1, 'conv2': _conv2, 'conv3': _conv3
            , 'pool': _pool, 'dense': _dense, 'out': _out
        }
        return out
print ("CNN ready")
```

```
CNN ready
```

DEFINE COMPUTATIONAL GRAPH

```
# tf Graph input
x = tf.placeholder(tf.float32, [None, n_input])
y = tf.placeholder(tf.float32, [None, n_output])
# Parameters
learning_rate   = 0.001
training_epochs = 5
batch_size      = 100
display_step    = 1
# Functions!
with tf.device('/cpu:0'): # <= This is optional
    _pred = conv_simple(x, weights, biases)['out']
    cost = tf.reduce_mean(tf.nn.softmax_cross_entropy_with_logits(_pred, y))
    optm = tf.train.AdamOptimizer(learning_rate=learning_rate).minimize(cost)
    _corr = tf.equal(tf.argmax(_pred,1), tf.argmax(y,1)) # Count corrects
    accr = tf.reduce_mean(tf.cast(_corr, tf.float32)) # Accuracy
    init = tf.initialize_all_variables()
# Saver
save_step = 1;
savedir = "nets/"
saver = tf.train.Saver(max_to_keep=3)
print ("Network Ready to Go!")
```

```
Network Ready to Go!
```

OPTIMIZE

DO TRAIN OR NOT

```
do_train = 1
sess = tf.Session()
sess.run(init)
```

```
if do_train == 1:
    for epoch in range(training_epochs):
        avg_cost = 0.
        total_batch = int(mnist.train.num_examples/batch_size)
        # Loop over all batches
        for i in range(total_batch):
            batch_xs, batch_ys = mnist.train.next_batch(batch_size)
            # Fit training using batch data
            sess.run(optm, feed_dict={x: batch_xs, y: batch_ys})
            # Compute average loss
            avg_cost += sess.run(cost, feed_dict={x: batch_xs, y: batch_ys})/total_batch

        # Display logs per epoch step
        if epoch % display_step == 0:
            print ("Epoch: %03d/%03d cost: %.9f" % (epoch, training_epochs, avg_cost))
            train_acc = sess.run(accr, feed_dict={x: batch_xs, y: batch_ys})
            print (" Training accuracy: %.3f" % (train_acc))
            test_acc = sess.run(accr, feed_dict={x: testimg, y: testlabel})
            print (" Test accuracy: %.3f" % (test_acc))

        # Save Net
        if epoch % save_step == 0:
            saver.save(sess, "nets/cnn_mnist_simple.ckpt-" + str(epoch))

    print ("Optimization Finished.")
```

```python
if do_train == 1:
    for epoch in range(training_epochs):
        avg_cost = 0.
        total_batch = int(mnist.train.num_examples/batch_size)
        # Loop over all batches
        for i in range(total_batch):
            batch_xs, batch_ys = mnist.train.next_batch(batch_size)
            # Fit training using batch data
            sess.run(optm, feed_dict={x: batch_xs, y: batch_ys})
            # Compute average loss
            avg_cost += sess.run(cost, feed_dict

        # Display logs per epoch step
        if epoch % display_step == 0:
            print ("Epoch: %03d/%03d cost: %.9f"
            train_acc = sess.run(accr, feed_dict
            print (" Training accuracy: %.3f" %
            test_acc = sess.run(accr, feed_dict=
            print (" Test accuracy: %.3f" % (tes

        # Save Net
        if epoch % save_step == 0:
            saver.save(sess, "nets/cnn_mnist_sim

    print ("Optimization Finished.")
```

```
Epoch: 000/005 cost: 0.362760447
 Training accuracy: 0.960
 Test accuracy: 0.951
Epoch: 001/005 cost: 0.117072306
 Training accuracy: 0.980
 Test accuracy: 0.974
Epoch: 002/005 cost: 0.076811765
 Training accuracy: 0.960
 Test accuracy: 0.978
Epoch: 003/005 cost: 0.059349174
 Training accuracy: 0.980
 Test accuracy: 0.981
Epoch: 004/005 cost: 0.049465416
 Training accuracy: 0.980
 Test accuracy: 0.983
Optimization Finished.
```

RESTORE NETWORK

```
if do_train == 0:
    epoch = 4
    saver.restore(sess, "nets/cnn_mnist_simple.ckpt-" + str(epoch))
```

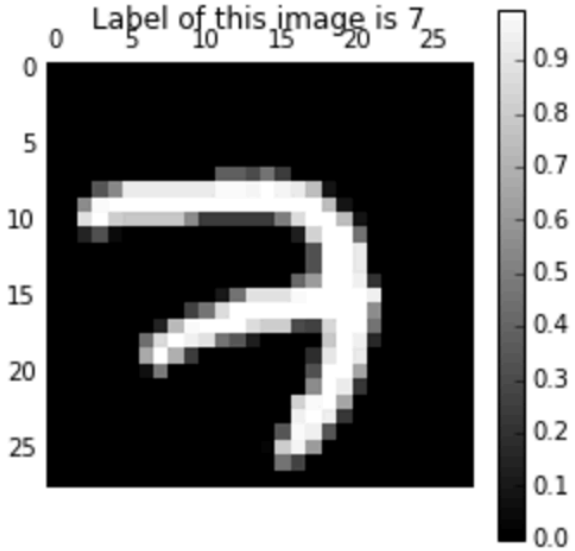
LET'S SEE HOW CNN WORKS

```
with tf.device('/cpu:0'):
    conv_out = conv_simple(x, weights, biases)

input_r = sess.run(conv_out['input_r'], feed_dict={x: trainimg[0:1, :]})
conv1   = sess.run(conv_out['conv1'], feed_dict={x: trainimg[0:1, :]})
conv2   = sess.run(conv_out['conv2'], feed_dict={x: trainimg[0:1, :]})
conv3   = sess.run(conv_out['conv3'], feed_dict={x: trainimg[0:1, :]})
pool    = sess.run(conv_out['pool'], feed_dict={x: trainimg[0:1, :]})
dense   = sess.run(conv_out['dense'], feed_dict={x: trainimg[0:1, :]})
out     = sess.run(conv_out['out'], feed_dict={x: trainimg[0:1, :]})
```

INPUT

```
print ("Size of 'input_r' is %s" % (input_r.shape,))
label = np.argmax(trainlabel[0, :])
print ("Label is %d" % (label))

# Plot !
plt.matshow(input_r[0, :, :, 0], cmap=plt.get_cmap('gray'))
plt.title("Label of this image is " + str(label) + "")
plt.colorbar()
plt.show()
```

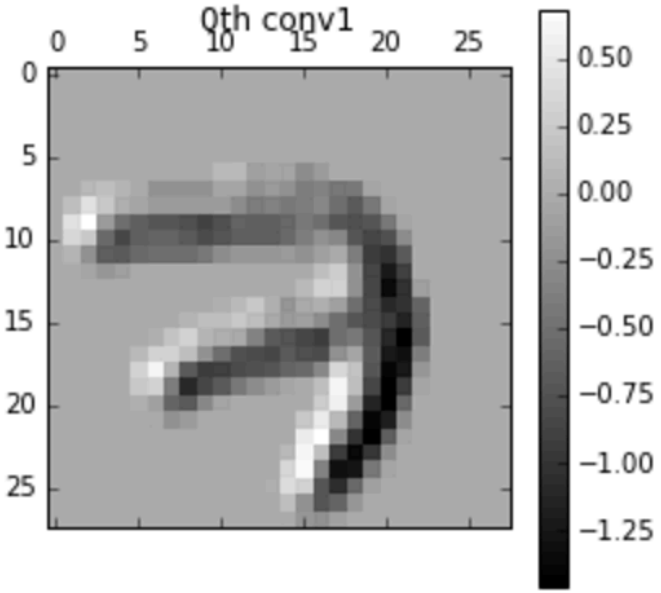
```
Size of 'input_r' is (1, 28, 28, 1)
Label is 7
```



CONV1 (CONVOLUTION)

```
print ("Size of 'conv1' is %s" % (conv1.shape,))

# PLOT
for i in range(64):
    plt.matshow(conv1[0, :, :, i], cmap=plt.get_cmap('gray'))
    plt.title(str(i) + "th conv1")
    plt.colorbar()
    plt.show()
```

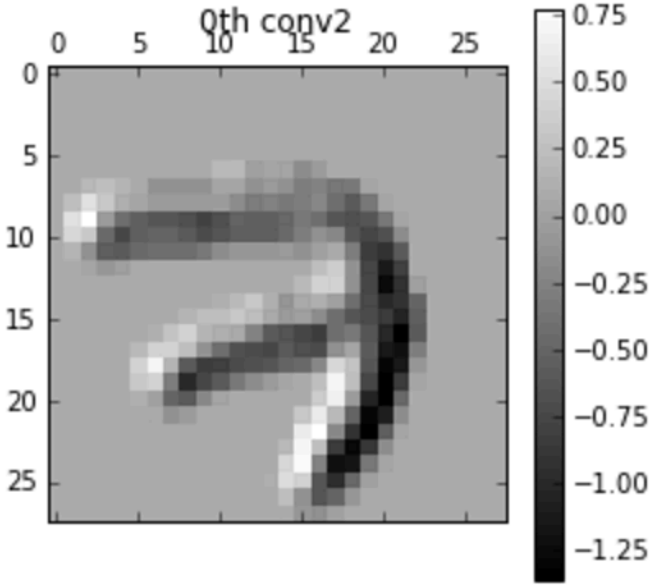
```
Size of 'conv1' is (1, 28, 28, 64)
```



CONV2 (+BIAS)

```
print ("Size of 'conv2' is %s" % (conv2.shape,))

# PLOT
for i in range(64):
    plt.matshow(conv2[0, :, :, i], cmap=plt.get_cmap('gray'))
    plt.title(str(i) + "th conv2")
    plt.colorbar()
    plt.show()
```

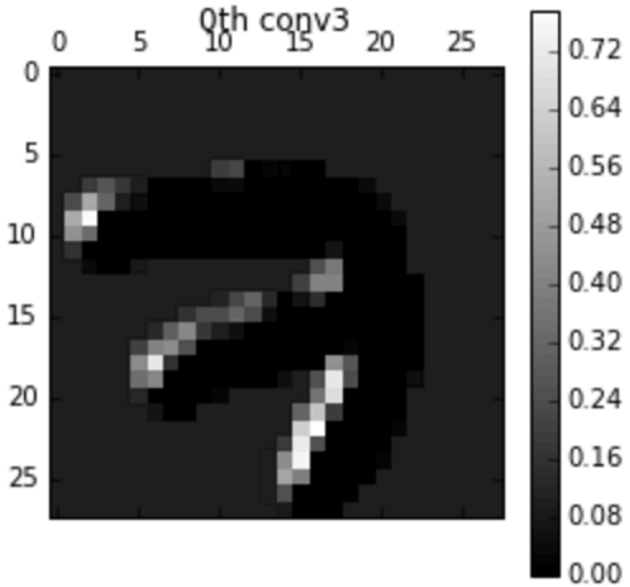
```
Size of 'conv2' is (1, 28, 28, 64)
```



CONV3 (RELU)

```
print ("Size of 'conv3' is %s" % (conv3.shape,))

# Plot !
for i in range(64):
    plt.matshow(conv3[0, :, :, i], cmap=plt.get_cmap('gray'))
    plt.title(str(i) + "th conv3")
    plt.colorbar()
    plt.show()
```

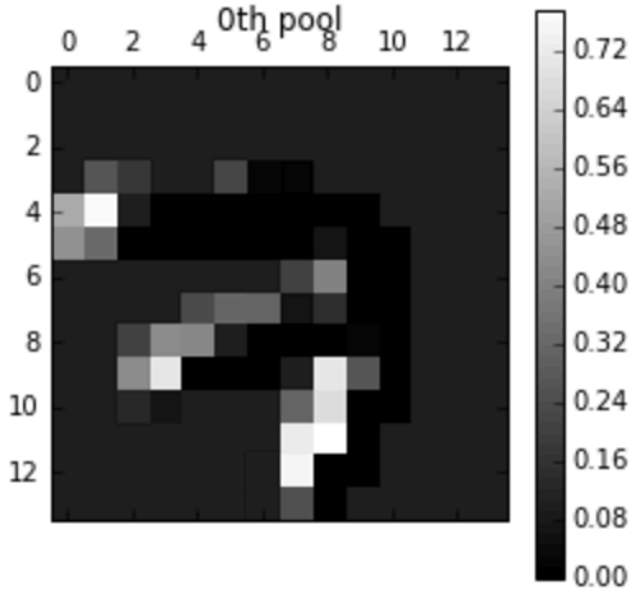
```
Size of 'conv3' is (1, 28, 28, 64)
```



POOL (MAX_POOL)

```
print ("Size of 'pool' is %s" % (pool.shape,))

# Plot !
for i in range(64):
    plt.matshow(pool[0, :, :, i], cmap=plt.get_cmap('gray'))
    plt.title(str(i) + "th pool")
    plt.colorbar()
    plt.show()
```

```
Size of 'pool' is (1, 14, 14, 64)
```



DENSE

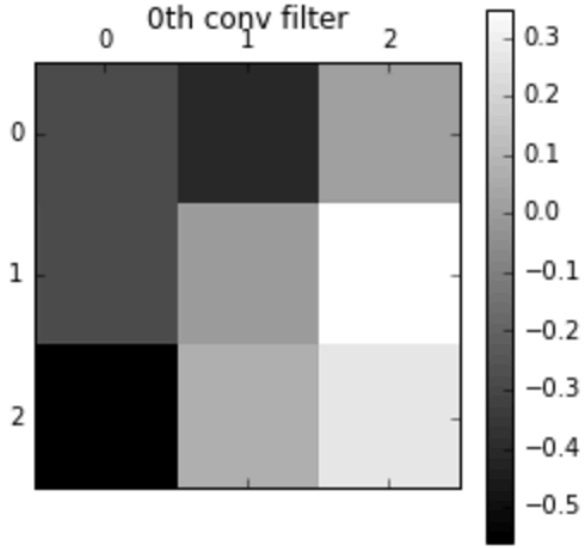
```
# Let's see 'dense'
print ("Size of 'dense' is %s" % (dense.shape,))
# Let's see 'out'
print ("Size of 'out' is %s" % (out.shape,))
```

```
Size of 'dense' is (1, 12544)
Size of 'out' is (1, 10)
```

CONVOLUTION FILTERS

```
# Let's see weight!
wc1 = sess.run(weights['wc1'])
print ("Size of 'wc1' is %s" % (wc1.shape,))

# Plot !
for i in range(64):
    plt.matshow(wc1[:, :, 0, i], cmap=plt.get_cmap('gray'))
    plt.title(str(i) + "th conv filter")
    plt.colorbar()
    plt.show()
```

```
Size of 'wc1' is (3, 3, 1, 64)
```



Implementing modern CNNs

- dropout + batch_norm

MODERN CONVOLUTIONAL NEURAL NETWORK

DROPOUT + BATCH NORMALIZATION

```
import numpy as np
import tensorflow as tf
import matplotlib.pyplot as plt
from tensorflow.examples.tutorials.mnist import input_data
%matplotlib inline
print ("PACKAGES LOADED")
```

```
PACKAGES LOADED
```

LOAD MNIST

```
mnist = input_data.read_data_sets('data/', one_hot=True)
trainimg   = mnist.train.images
trainlabel = mnist.train.labels
testimg    = mnist.test.images
testlabel  = mnist.test.labels
```

```
Extracting data/train-images-idx3-ubyte.gz
Extracting data/train-labels-idx1-ubyte.gz
Extracting data/t10k-images-idx3-ubyte.gz
Extracting data/t10k-labels-idx1-ubyte.gz
```

SELECT DEVICE TO BE USED

```
device_type = "/gpu:0"
```

DEFINE CNN

```
n_input  = 784
n_output = 10
with tf.device(device_type):
    weights  = {
        'wc1': tf.Variable(tf.truncated_normal([3, 3, 1, 64], stddev=0.1)),
        'wc2': tf.Variable(tf.truncated_normal([3, 3, 64, 128], stddev=0.1)),
        'wd1': tf.Variable(tf.truncated_normal([7*7*128, 1024], stddev=0.1)),
        'wd2': tf.Variable(tf.truncated_normal([1024, n_output], stddev=0.1))
    }
    biases   = {
        'bc1': tf.Variable(tf.random_normal([64], stddev=0.1)),
        'bc2': tf.Variable(tf.random_normal([128], stddev=0.1)),
        'bd1': tf.Variable(tf.random_normal([1024], stddev=0.1)),
        'bd2': tf.Variable(tf.random_normal([n_output], stddev=0.1))
    }
    def conv_basic(_input, _w, _b, _keepratio):
        # INPUT
        _input_r = tf.reshape(_input, shape=[-1, 28, 28, 1])
        # CONV LAYER 1
        _conv1 = tf.nn.conv2d(_input_r, _w['wc1'], strides=[1, 1, 1, 1], padding='SAME')
        _mean, _var = tf.nn.moments(_conv1, [0, 1, 2])
        _conv1 = tf.nn.batch_normalization(_conv1, _mean, _var, 0, 1, 0.0001)
        _conv1 = tf.nn.relu(tf.nn.bias_add(_conv1, _b['bc1']))
        _pool1 = tf.nn.max_pool(_conv1, ksize=[1, 2, 2, 1], strides=[1, 2, 2, 1], padding='SAME')
        _pool_dr1 = tf.nn.dropout(_pool1, _keepratio)
        # CONV LAYER 2
        _conv2 = tf.nn.conv2d(_pool_dr1, _w['wc2'], strides=[1, 1, 1, 1], padding='SAME')
        _mean, _var = tf.nn.moments(_conv2, [0, 1, 2])
        _conv2 = tf.nn.batch_normalization(_conv2, _mean, _var, 0, 1, 0.0001)
        _conv2 = tf.nn.relu(tf.nn.bias_add(_conv2, _b['bc2']))
        _pool2 = tf.nn.max_pool(_conv2, ksize=[1, 2, 2, 1], strides=[1, 2, 2, 1], padding='SAME')
        _pool_dr2 = tf.nn.dropout(_pool2, _keepratio)
        # VECTORIZE
        _dense1 = tf.reshape(_pool_dr2, [-1, _w['wd1'].get_shape().as_list()[0]])
        # FULLY CONNECTED LAYER 1
        _fc1 = tf.nn.relu(tf.add(tf.matmul(_dense1, _w['wd1']), _b['bd1']))
        _fc_dr1 = tf.nn.dropout(_fc1, _keepratio)
        # FULLY CONNECTED LAYER 2
        _out = tf.add(tf.matmul(_fc_dr1, _w['wd2']), _b['bd2'])
        # RETURN
        out = { 'input_r': _input_r, 'conv1': _conv1, 'pool1': _pool1, 'pool1_dr1': _pool_dr1,
            'conv2': _conv2, 'pool2': _pool2, 'pool_dr2': _pool_dr2, 'dense1': _dense1,
            'fc1': _fc1, 'fc_dr1': _fc_dr1, 'out': _out
        }
        return out
print ("CNN READY")
```

```
weights  = {
    'wc1': tf.Variable(tf.truncated_normal([3, 3, 1, 64], stddev=0.1)),
    'wc2': tf.Variable(tf.truncated_normal([3, 3, 64, 128], stddev=0.1)),
    'wd1': tf.Variable(tf.truncated_normal([7*7*128, 1024], stddev=0.1)),
    'wd2': tf.Variable(tf.truncated_normal([1024, n_output], stddev=0.1))
}
biases   = {
    'bc1': tf.Variable(tf.random_normal([64], stddev=0.1)),
    'bc2': tf.Variable(tf.random_normal([128], stddev=0.1)),
    'bd1': tf.Variable(tf.random_normal([1024], stddev=0.1)),
    'bd2': tf.Variable(tf.random_normal([n_output], stddev=0.1))
}
```

```python
def conv_basic(_input, _w, _b, _keepratio):
    # INPUT
    _input_r = tf.reshape(_input, shape=[-1, 28, 28, 1])
    # CONV LAYER 1
    _conv1 = tf.nn.conv2d(_input_r, _w['wc1'], strides=[1, 1, 1, 1], padding='SAME')
    _mean, _var = tf.nn.moments(_conv1, [0, 1, 2])
    _conv1 = tf.nn.batch_normalization(_conv1, _mean, _var, 0, 1, 0.0001)
    _conv1 = tf.nn.relu(tf.nn.bias_add(_conv1, _b['bc1']))
    _pool1 = tf.nn.max_pool(_conv1, ksize=[1, 2, 2, 1], strides=[1, 2, 2, 1], padding='SAME')
    _pool_dr1 = tf.nn.dropout(_pool1, _keepratio)
    # CONV LAYER 2
    _conv2 = tf.nn.conv2d(_pool_dr1, _w['wc2'], strides=[1, 1, 1, 1], padding='SAME')
    _mean, _var = tf.nn.moments(_conv2, [0, 1, 2])
    _conv2 = tf.nn.batch_normalization(_conv2, _mean, _var, 0, 1, 0.0001)
    _conv2 = tf.nn.relu(tf.nn.bias_add(_conv2, _b['bc2']))
    _pool2 = tf.nn.max_pool(_conv2, ksize=[1, 2, 2, 1], strides=[1, 2, 2, 1], padding='SAME')
    _pool_dr2 = tf.nn.dropout(_pool2, _keepratio)
    # VECTORIZE
    _dense1 = tf.reshape(_pool_dr2, [-1, _w['wd1'].get_shape().as_list()[0]])
    # FULLY CONNECTED LAYER 1
    _fc1 = tf.nn.relu(tf.add(tf.matmul(_dense1, _w['wd1']), _b['bd1']))
    _fc_dr1 = tf.nn.dropout(_fc1, _keepratio)
    # FULLY CONNECTED LAYER 2
    _out = tf.add(tf.matmul(_fc_dr1, _w['wd2']), _b['bd2'])
    # RETURN
    out = { 'input_r': _input_r, 'conv1': _conv1, 'pool1': _pool1, 'pool1_dr1': _pool_dr1,
        'conv2': _conv2, 'pool2': _pool2, 'pool_dr2': _pool_dr2, 'dense1': _dense1,
        'fc1': _fc1, 'fc_dr1': _fc_dr1, 'out': _out
    }
    return out
```

tf.nn.dropout

```
tf.nn.dropout(x, keep_prob, noise_shape=None,
seed=None, name=None)
```

Computes dropout.

With probability `keep_prob`, outputs the input element scaled up by `1 / keep_prob`, otherwise outputs `0`. The scaling is so that the expected sum is unchanged.

By default, each element is kept or dropped independently. If `noise_shape` is specified, it must be broadcastable to the shape of `x`, and only dimensions with `noise_shape[i] == shape(x)[i]` will make independent decisions. For example, if `shape(x) = [k, l, m, n]` and `noise_shape = [k, 1, 1, n]`, each batch and channel component will be kept independently and each row and column will be kept or not kept together.

Args:

- `x`: A tensor.
- `keep_prob`: A scalar `Tensor` with the same type as x. The probability that each element is kept.
- `noise_shape`: A 1-D `Tensor` of type `int32`, representing the shape for randomly generated keep/drop flags.
- `seed`: A Python integer. Used to create random seeds. See `set_random_seed` for behavior.
- `name`: A name for this operation (optional).

Returns:

A Tensor of the same shape of `x`.

Raises:

- `ValueError`: If `keep_prob` is not in `(0, 1]`.

tf.nn.moments

`tf.nn.moments(x, axes, shift=None, name=None, keep_dims=False)`

Calculate the mean and variance of `x`.

The mean and variance are calculated by aggregating the contents of `x` across `axes`. If `x` is 1-D and `axes = [0]` this is just the mean and variance of a vector.

When using these moments for batch normalization (see `tf.nn.batch_normalization`): * for so-called "global normalization", used with convolutional filters with shape `[batch, height, width, depth]`, pass `axes=[0, 1, 2]`. * for simple batch normalization pass `axes=[0]` (batch only).

Args:

- `x`: A `Tensor`.
- `axes`: array of ints. Axes along which to compute mean and variance.
- `shift`: A `Tensor` containing the value by which to shift the data for numerical stability, or `None` if no shift is to be performed. A shift close to the true mean provides the most numerically stable results.
- `name`: Name used to scope the operations that compute the moments.
- `keep_dims`: produce moments with the same dimensionality as the input.

Returns:

Two `Tensor` objects: `mean` and `variance`.

tf.nn.batch_normalization

```
tf.nn.batch_normalization(x, mean, variance, offset,
scale, variance_epsilon, name=None)
```

Batch normalization.

As described in http://arxiv.org/abs/1502.03167. Normalizes a tensor by `mean` and `variance`, and applies (optionally) a `scale` γ to it, as well as an `offset` $beta$:

$$\frac{\gamma(x-\mu)}{\sigma} + beta$$

`mean`, `variance`, `offset` and `scale` are all expected to be of one of two shapes: * In all generality, they can have the same number of dimensions as the input `x`, with identical sizes as `x` for the dimensions that are not normalized over (the 'depth' dimension(s)), and dimension 1 for the others which are being normalized over. `mean` and `variance` in this case would typically be the outputs of `tf.nn.moments(..., keep_dims=True)` during training, or running averages thereof during inference. * In the common case where the 'depth' dimension is the last dimension in the input tensor `x`, they may be one dimensional tensors of the same size as the 'depth' dimension. This is the case for example for the common `[batch, depth]` layout of fully-connected layers, and `[batch, height, width, depth]` for convolutions. `mean` and `variance` in this case would typically be the outputs of `tf.nn.moments(..., keep_dims=False)` during training, or running averages thereof during inference.

DEFINE COMPUTATIONAL GRAPH

```
# PLACEHOLDERS
x = tf.placeholder(tf.float32, [None, n_input])
y = tf.placeholder(tf.float32, [None, n_output])
keepratio = tf.placeholder(tf.float32)

# FUNCTIONS
with tf.device(device_type):
    _pred = conv_basic(x, weights, biases, keepratio)['out']
    cost = tf.reduce_mean(tf.nn.softmax_cross_entropy_with_logits(_pred, y))
    optm = tf.train.AdamOptimizer(learning_rate=0.001).minimize(cost)
    _corr = tf.equal(tf.argmax(_pred,1), tf.argmax(y,1))
    accr = tf.reduce_mean(tf.cast(_corr, tf.float32))
    init = tf.initialize_all_variables()

# SAVER
save_step = 1
saver = tf.train.Saver(max_to_keep=3)
print ("GRAPH READY")
```

```
GRAPH READY
```

OPTIMIZE

DO TRAIN OR NOT

```
do_train = 1
sess = tf.Session(config=tf.ConfigProto(allow_soft_placement=True))
sess.run(init)
```

```
training_epochs = 10
batch_size      = 100
display_step    = 1
if do_train == 1:
    for epoch in range(training_epochs):
        avg_cost = 0.
        total_batch = int(mnist.train.num_examples/batch_size)
        # Loop over all batches
        for i in range(total_batch):
            batch_xs, batch_ys = mnist.train.next_batch(batch_size)
            # Fit training using batch data
            sess.run(optm, feed_dict={x: batch_xs, y: batch_ys, keepratio:0.7})
            # Compute average loss
            avg_cost += sess.run(cost, feed_dict={x: batch_xs, y: batch_ys, keepratio:1.})/total_batch

        # Display logs per epoch step
        if epoch % display_step == 0:
            print ("Epoch: %03d/%03d cost: %.9f" % (epoch, training_epochs, avg_cost))
            train_acc = sess.run(accr, feed_dict={x: batch_xs, y: batch_ys, keepratio:1.})
            print (" Training accuracy: %.3f" % (train_acc))
            test_acc = sess.run(accr, feed_dict={x: testimg, y: testlabel, keepratio:1.})
            print (" Test accuracy: %.3f" % (test_acc))

        # Save Net
        if epoch % save_step == 0:
            saver.save(sess, "nets/cnn_mnist_basic.ckpt-" + str(epoch))

    print ("OPTIMIZATION FINISHED")
```

```
training_epochs = 10
batch_size      = 100
display_step    = 1
if do_train == 1:
    for epoch in range(training_epochs):
        avg_cost = 0.
        total_batch = int(mnist.train.num_examples/batch_s
        # Loop over all batches
        for i in range(total_batch):
            batch_xs, batch_ys = mnist.train.next_batch(ba
            # Fit training using batch data
            sess.run(optm, feed_dict={x: batch_xs, y: batc
            # Compute average loss
            avg_cost += sess.run(cost, feed_dict={x: batch

        # Display logs per epoch step
        if epoch % display_step == 0:
            print ("Epoch: %03d/%03d cost: %.9f" % (epoch,
            train_acc = sess.run(accr, feed_dict={x: batch
            print (" Training accuracy: %.3f" % (train_acc
            test_acc = sess.run(accr, feed_dict={x: testim
            print (" Test accuracy: %.3f" % (test_acc))

        # Save Net
        if epoch % save_step == 0:
            saver.save(sess, "nets/cnn_mnist_basic.ckpt-"

    print ("OPTIMIZATION FINISHED")
```

```
Epoch: 000/010 cost: 0.646904730
 Training accuracy: 0.980
 Test accuracy: 0.963
Epoch: 001/010 cost: 0.093934917
 Training accuracy: 0.970
 Test accuracy: 0.976
Epoch: 002/010 cost: 0.065349482
 Training accuracy: 0.990
 Test accuracy: 0.984
Epoch: 003/010 cost: 0.051335570
 Training accuracy: 0.990
 Test accuracy: 0.983
Epoch: 004/010 cost: 0.041595699
 Training accuracy: 0.960
 Test accuracy: 0.988
Epoch: 005/010 cost: 0.035545130
 Training accuracy: 0.990
 Test accuracy: 0.989
Epoch: 006/010 cost: 0.031783653
 Training accuracy: 0.970
 Test accuracy: 0.989
Epoch: 007/010 cost: 0.028224952
 Training accuracy: 1.000
 Test accuracy: 0.991
Epoch: 008/010 cost: 0.024041305
 Training accuracy: 0.990
 Test accuracy: 0.990
Epoch: 009/010 cost: 0.023118890
 Training accuracy: 0.990
 Test accuracy: 0.991
OPTIMIZATION FINISHED
```

RESTORE ¶

```
if do_train == 0:
    epoch = training_epochs-1
    saver.restore(sess, "nets/cnn_mnist_basic.ckpt-" + str(epoch))
```

COMPUTE TEST ACCURACY

```
test_acc = sess.run(accr, feed_dict={x: testimg, y: testlabel, keepratio:1.})
print (" TEST ACCURACY: %.3f" % (test_acc))
```

```
 TEST ACCURACY: 0.991
```