Deep Learning Topics: Skip Connections, and the Keras Model API

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(SDSC)
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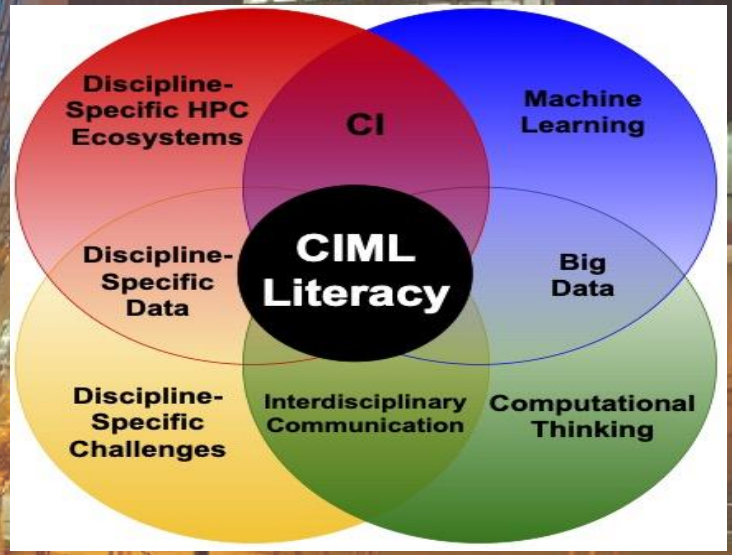
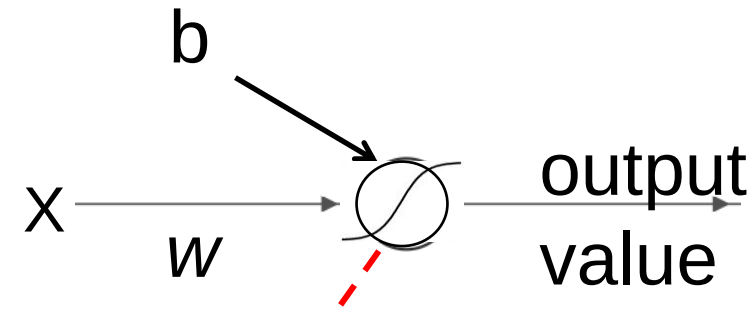


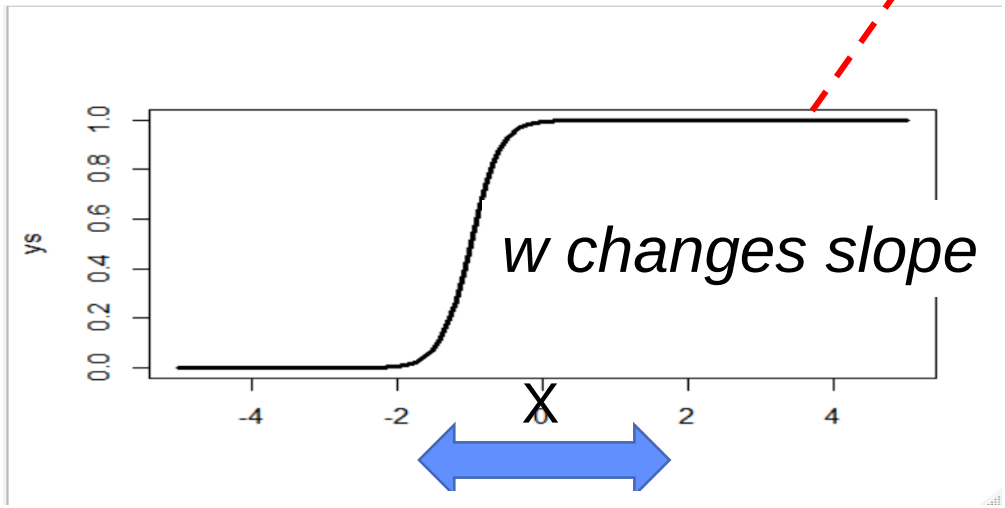
Outline

- Gate connection idea
- Skip and Residual connections
- Keras Model API
- Exercise MNIST Autoencoding

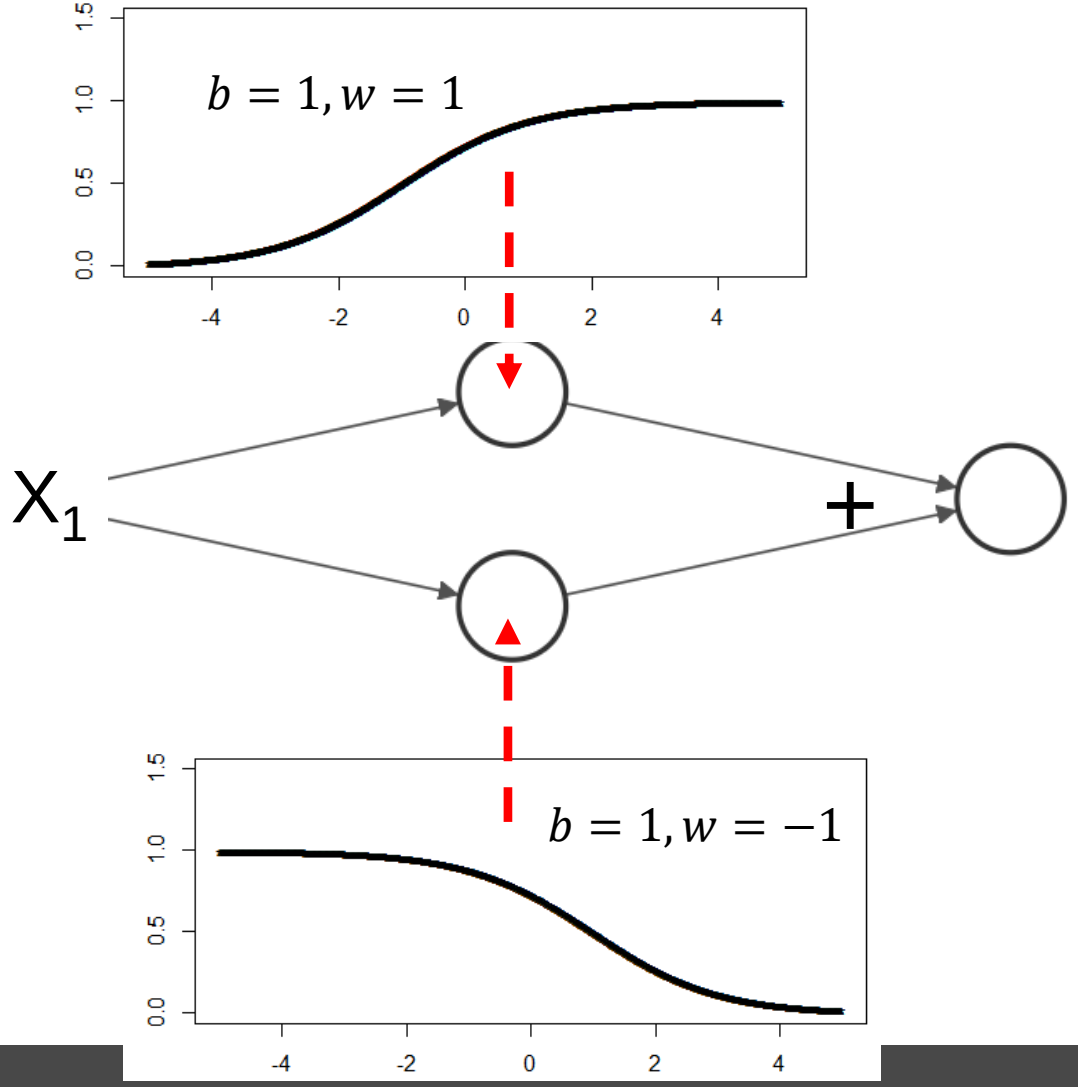
Recall: the logistic unit

$$f(x) = \frac{1}{1 + exp^{(-(b+wx))}}$$

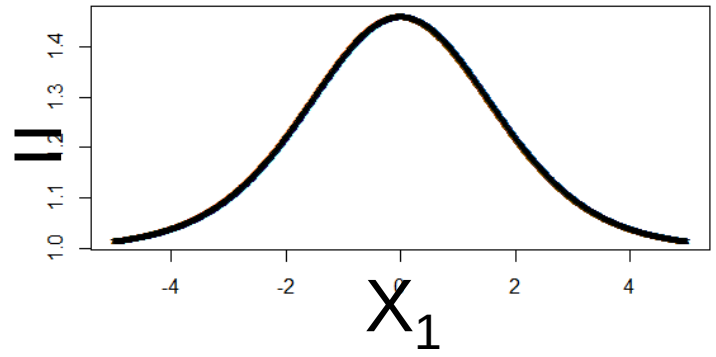




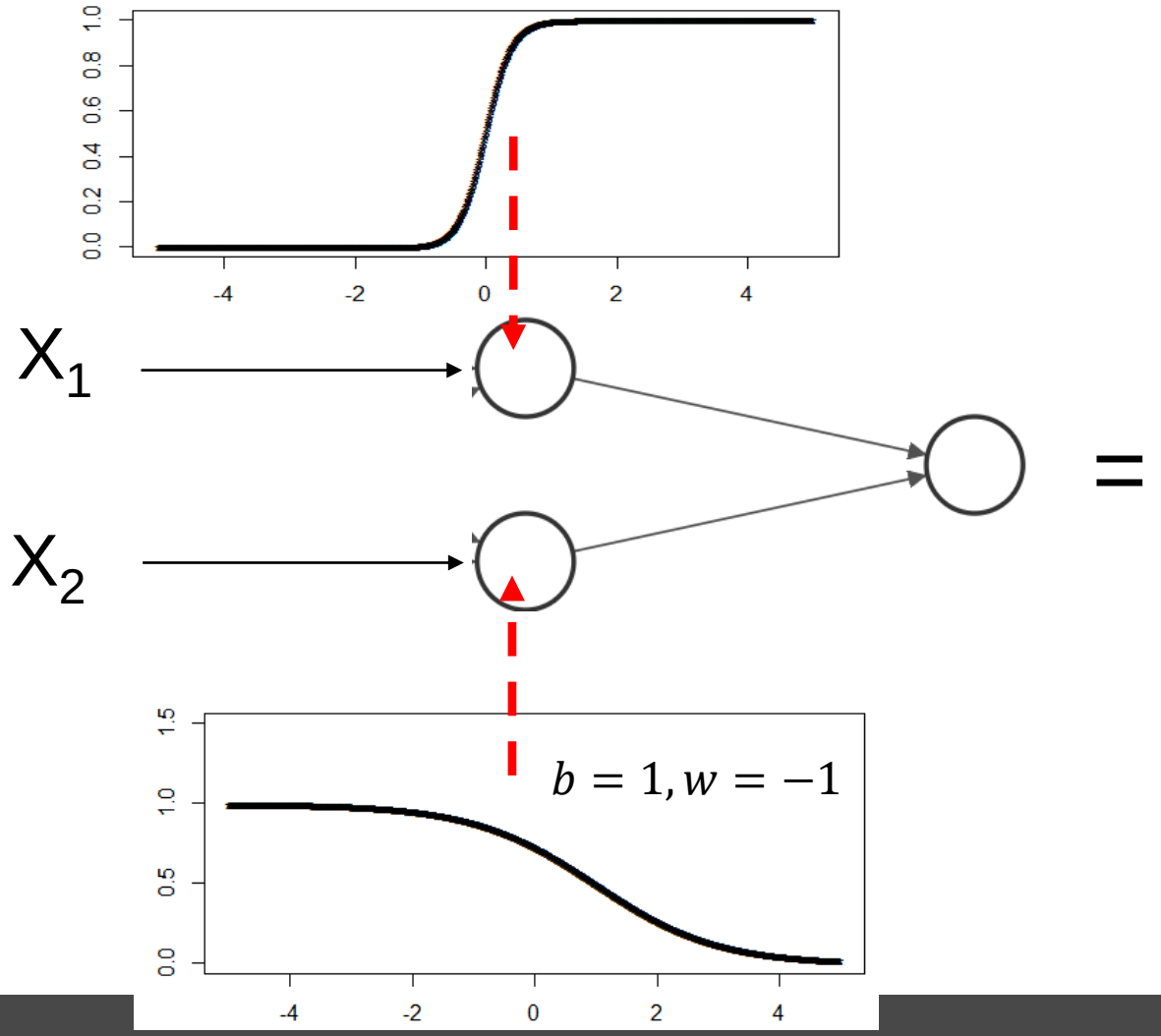
Example: 1 input into 2 logistic units with these activations



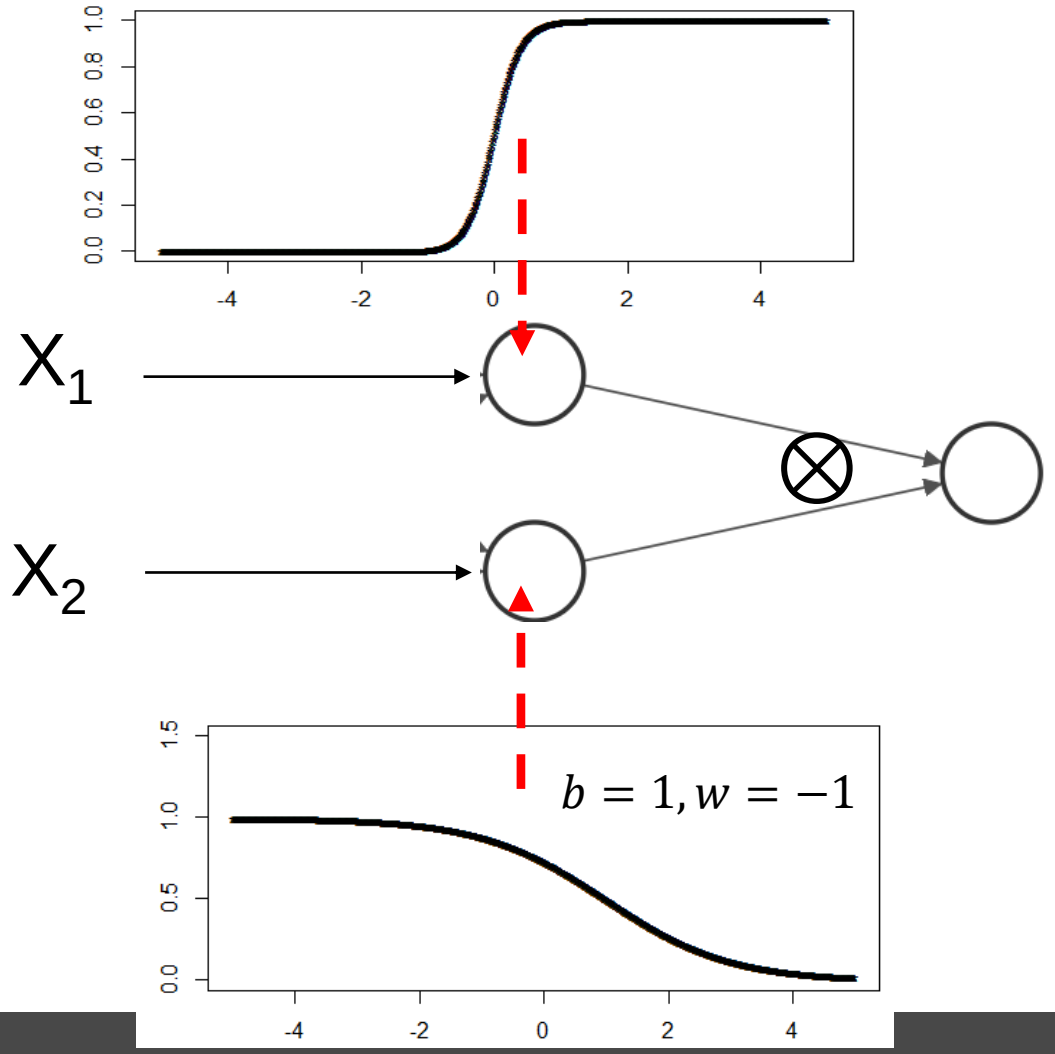
If you add these 2 units into a final output unit what would the output function look like?



Example: 2 input into 2 logistic units with these activations



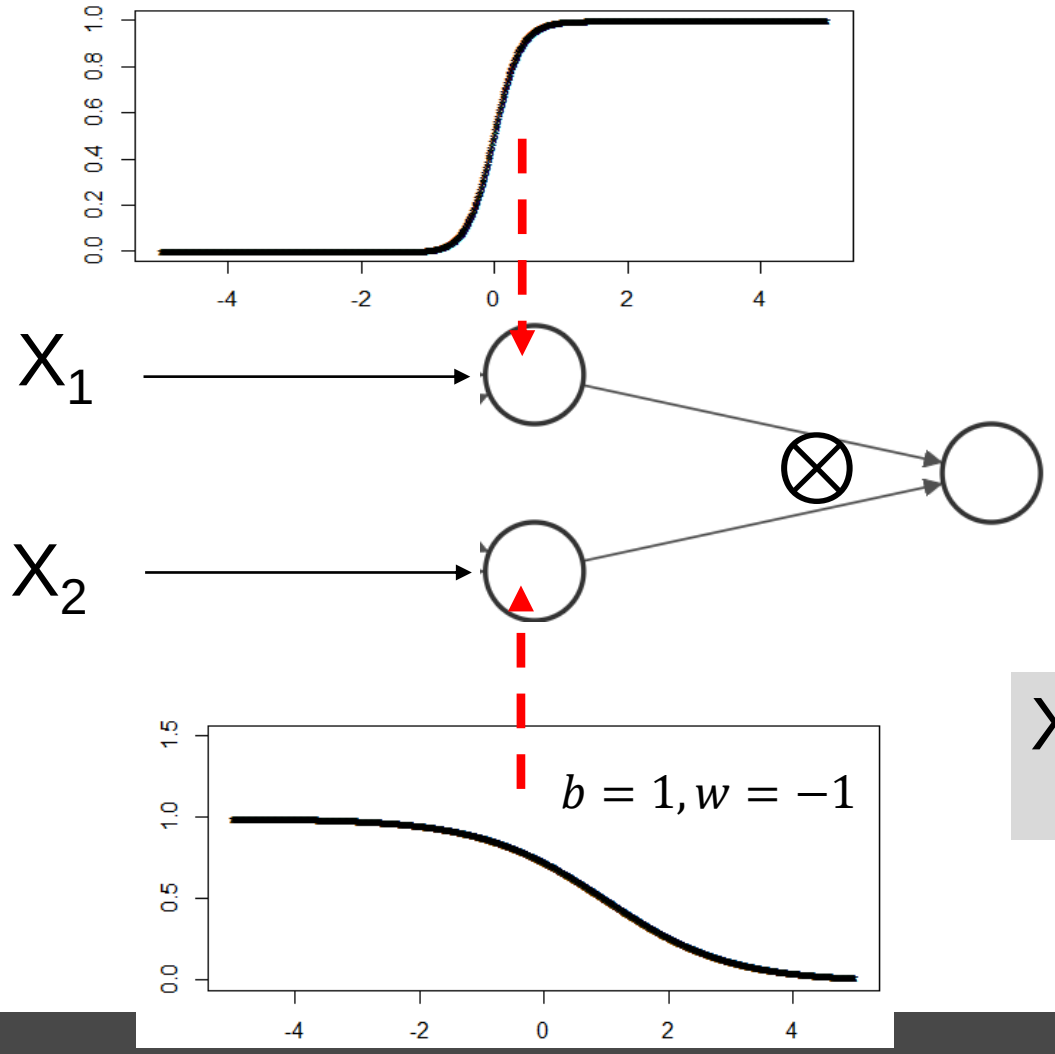
Example: 2 input into 2 logistic units with these activations



= ?

What if you multiply these? What is the output function doing?

Example: 2 input into 2 logistic units with these activations

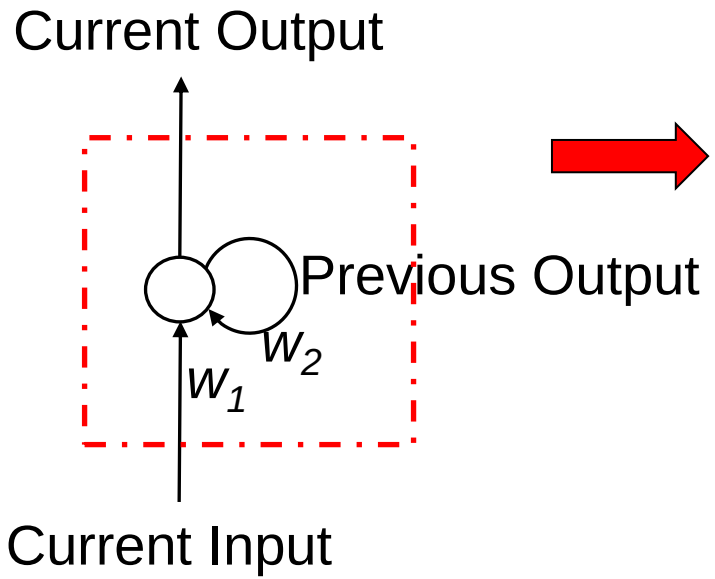


What if you multiply these? What is the output function doing?

$$= \begin{cases} 0 & \text{if } X_1 < 0 \\ h(X_2) & \text{if } X_1 > 0 \end{cases}$$

X_1"gates" X_2 activation

A recurrent unit for sequence learning can be replaced by a gated unit



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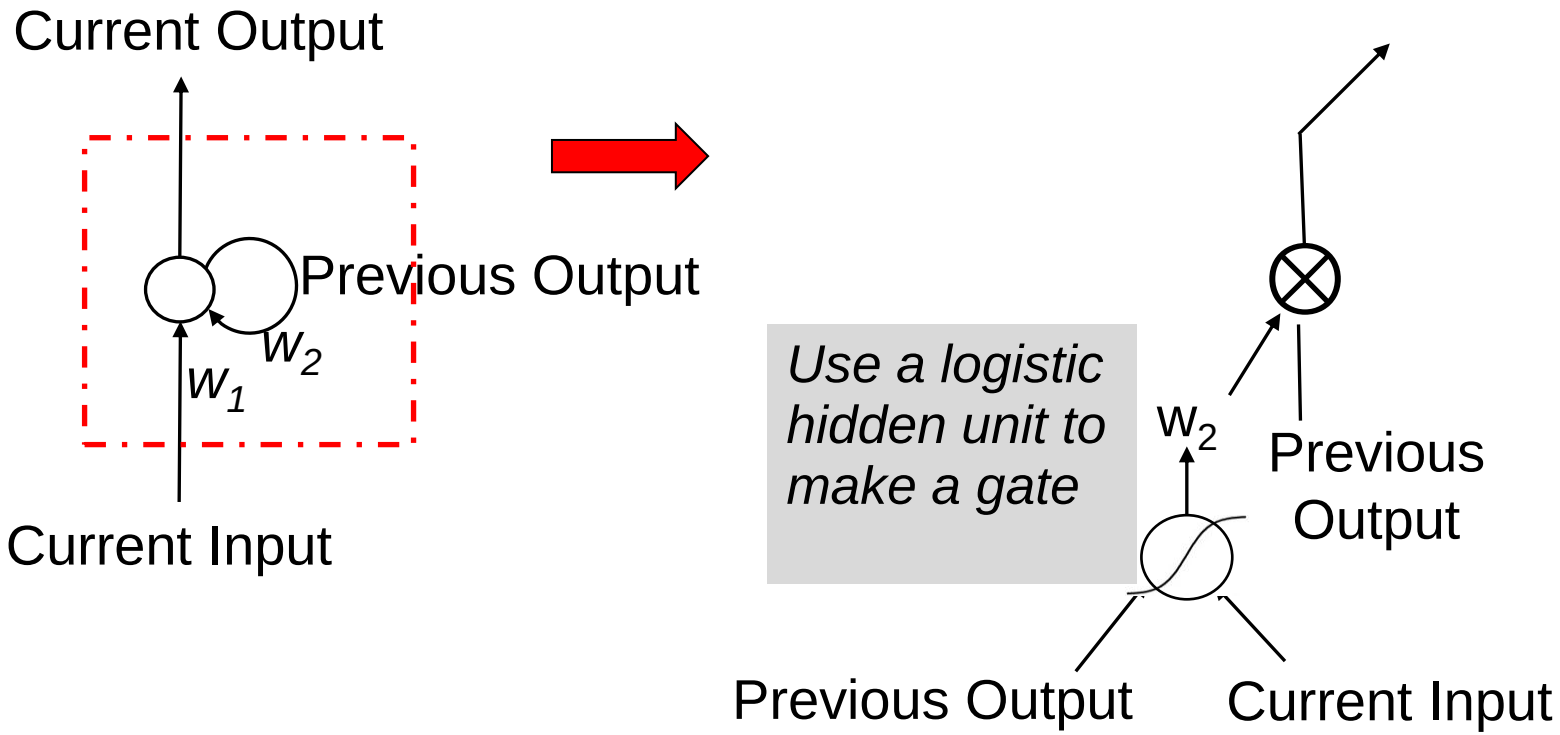

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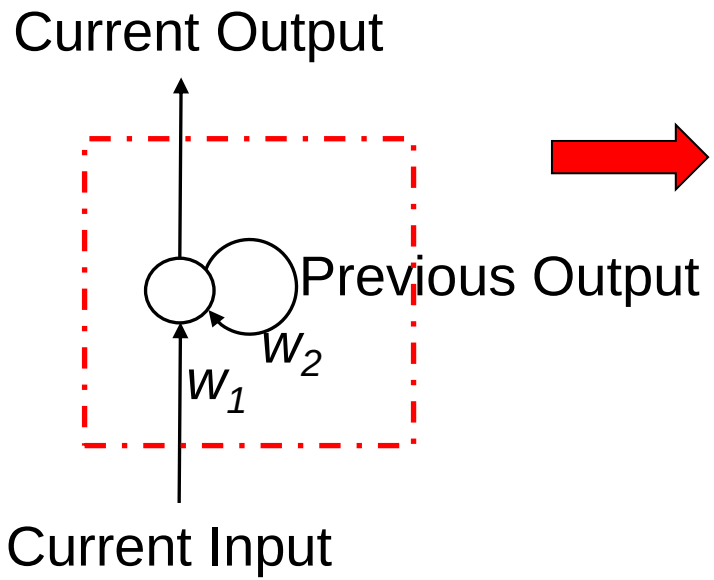
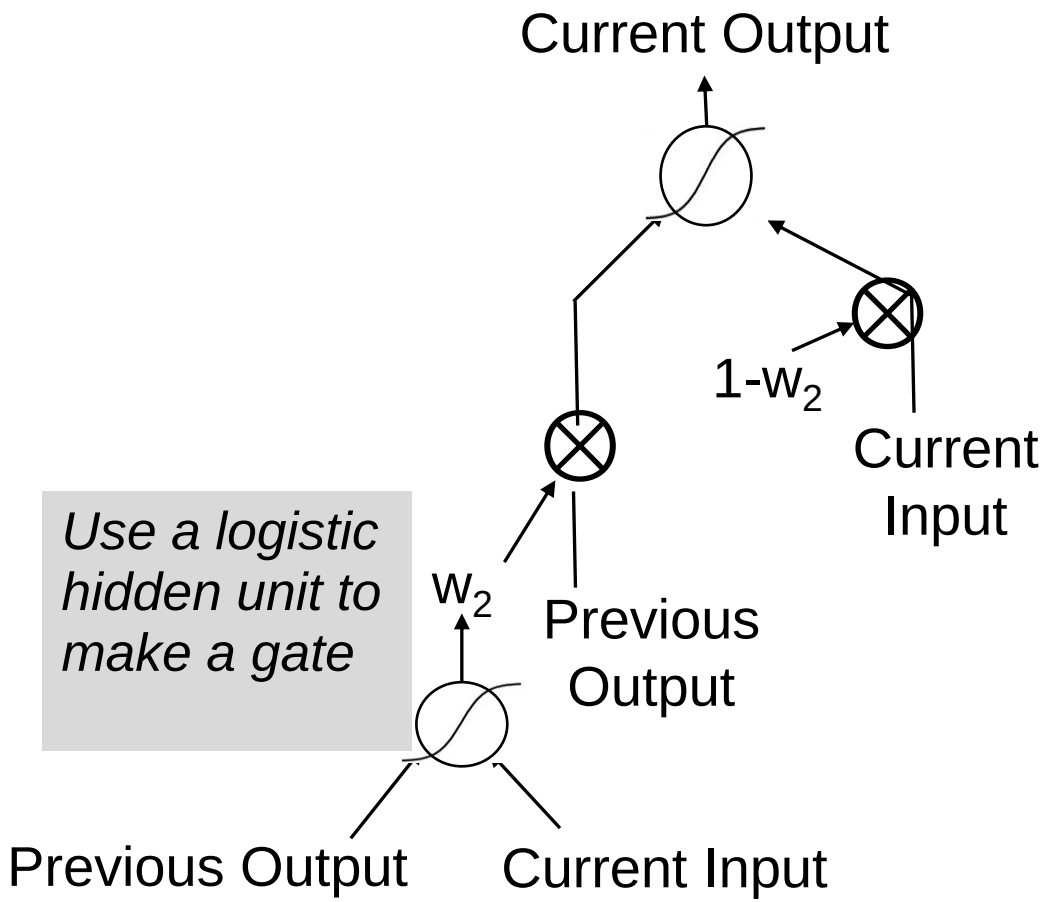


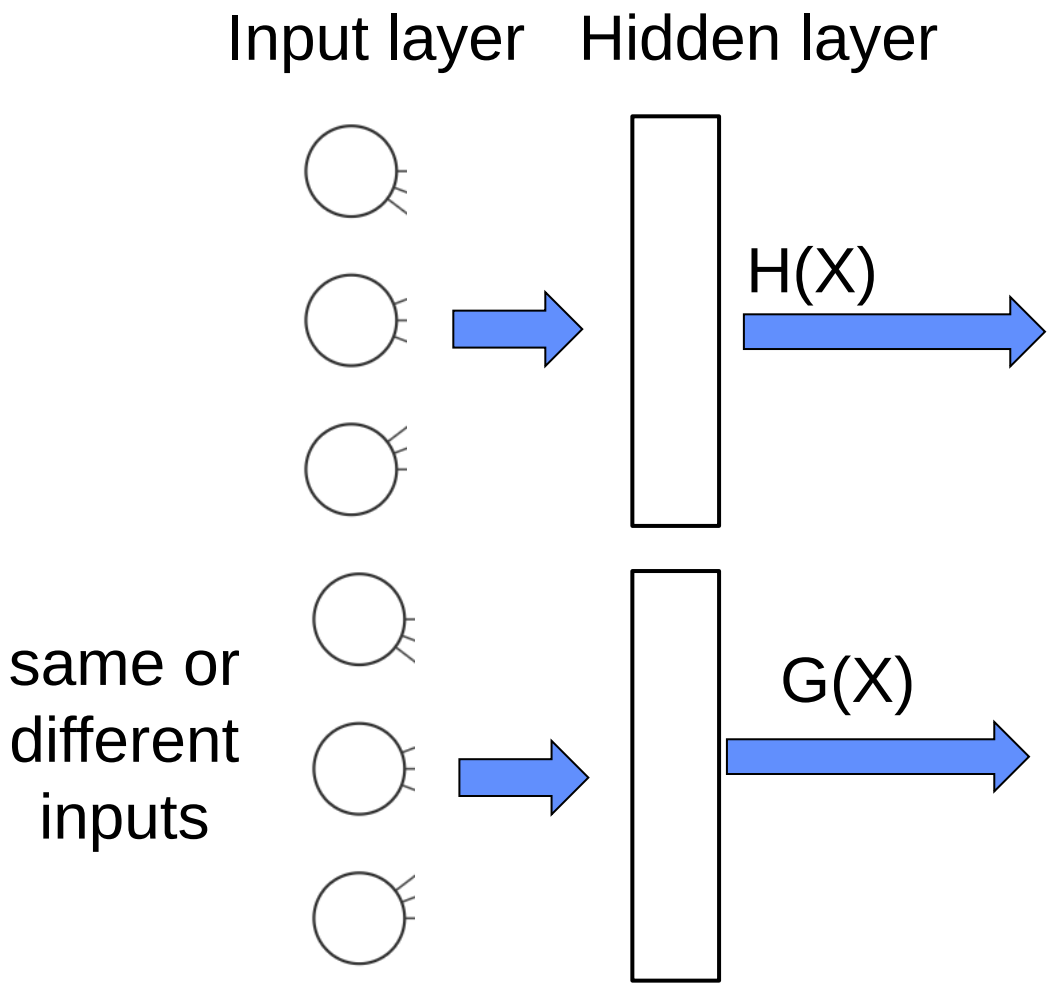


Use a logistic hidden unit to make a gate

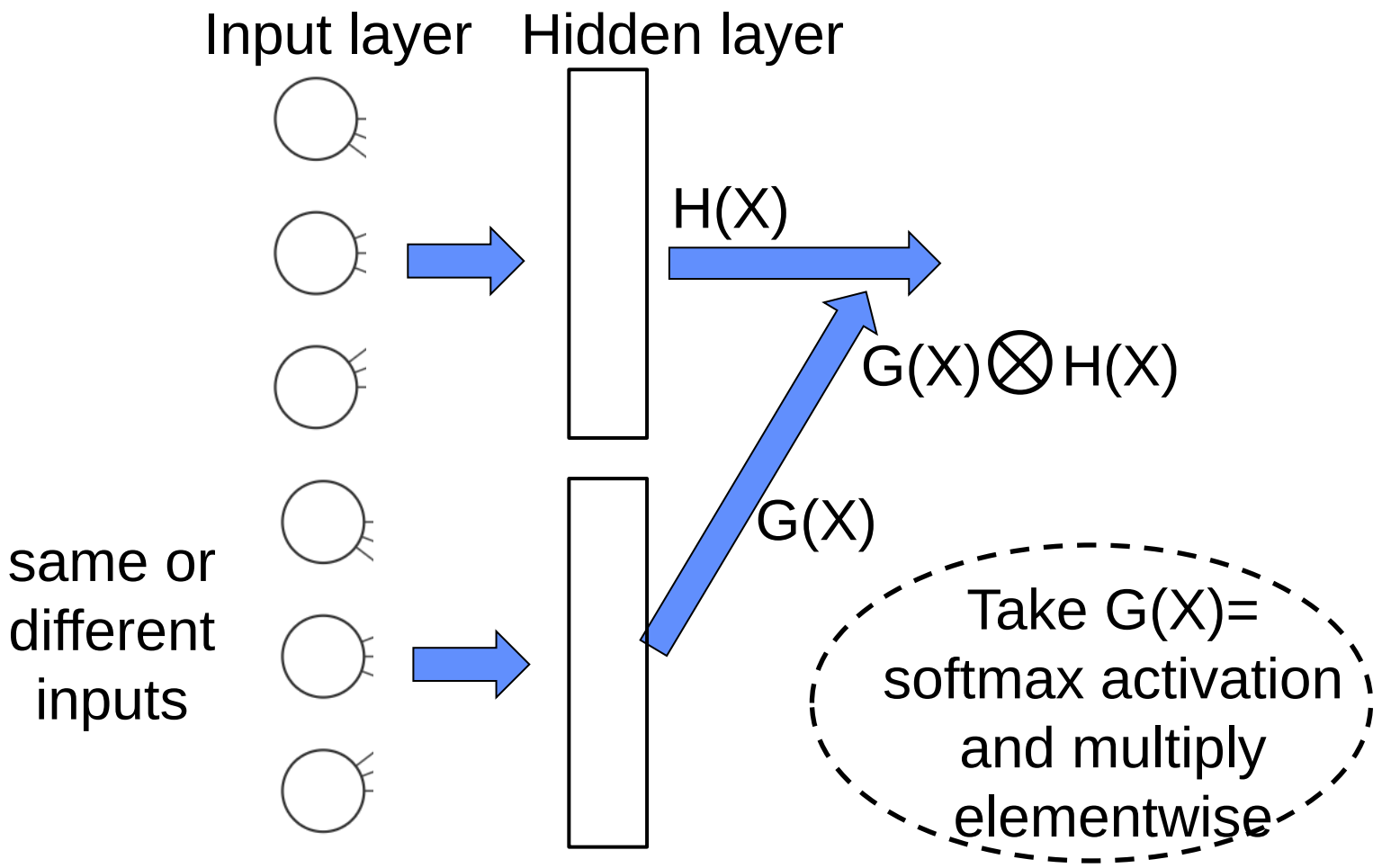
Use the gate to either keep previous output or update it with current input

'Gated Recurrent Unit' Cho, Bengio 2015

Redrawing the gate for two sets of hidden units



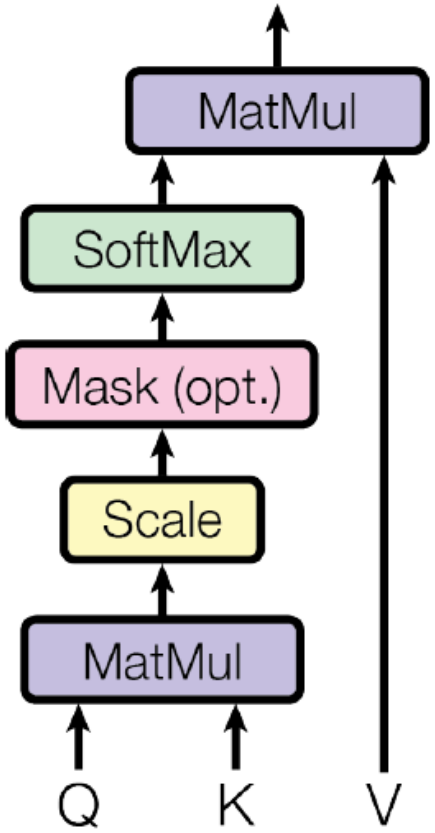
Use softmax for G(X) to get gating weights



Recall: softmax normalizes outputs into probability weights

Scaled Dot-Product Attention
(very rough summary)

"Attention" mechanism in language transformers use a softmax gate



The gate is applied to possible Values (V) for decoding

English vs French Words 'align' to make a gate

Vaswani, et al. 2017
Attention Is All You Need (for Transformers)

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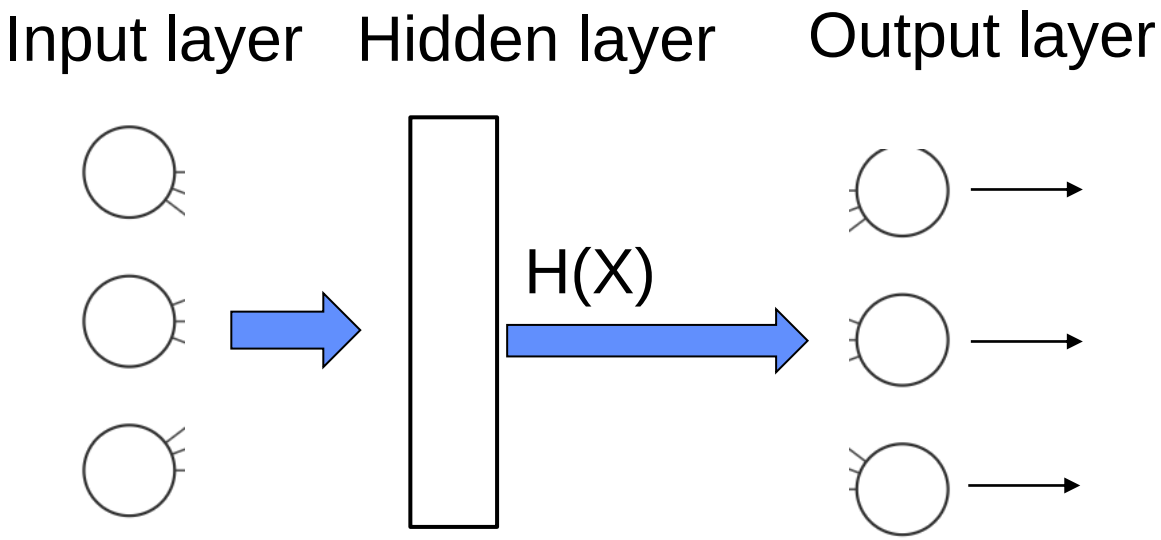
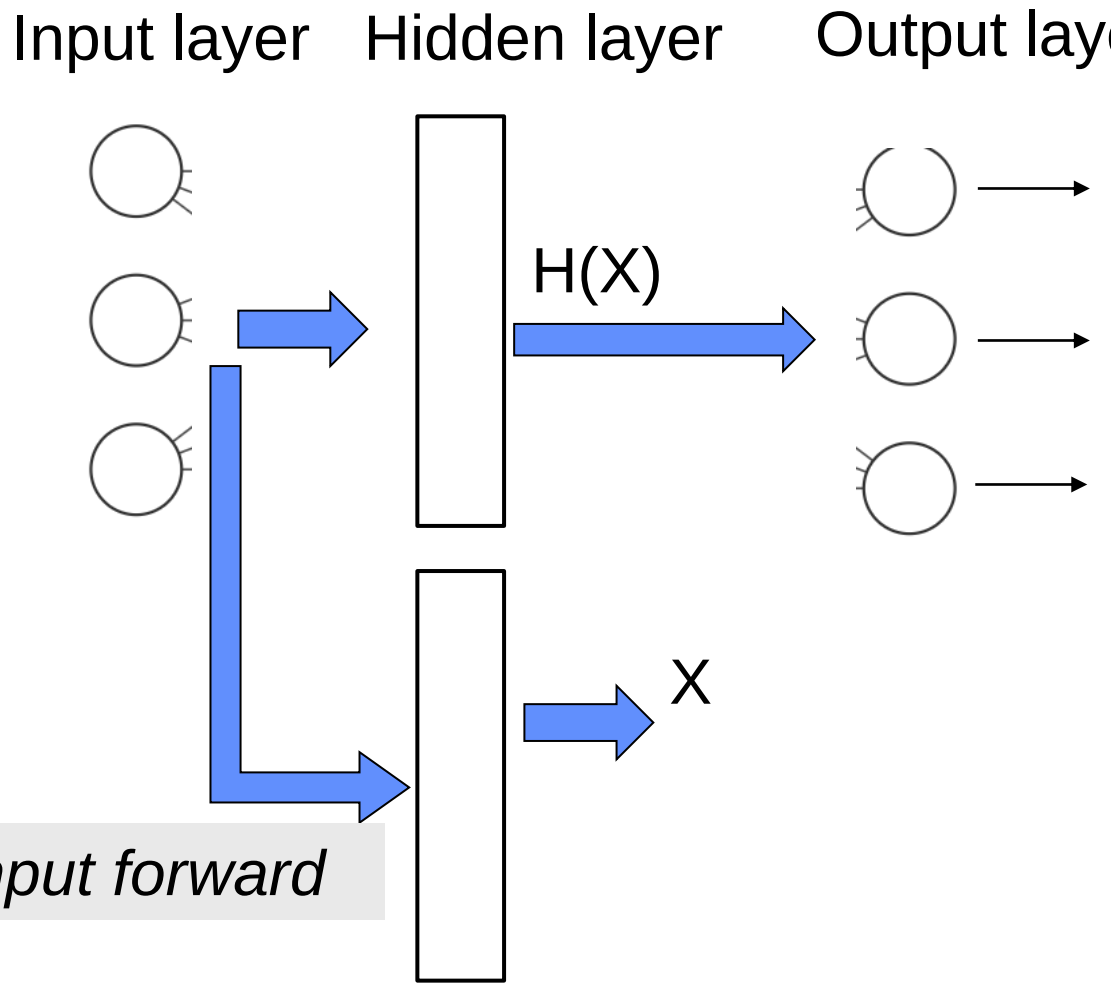
Recall the Multilayer Perceptron (MLP)

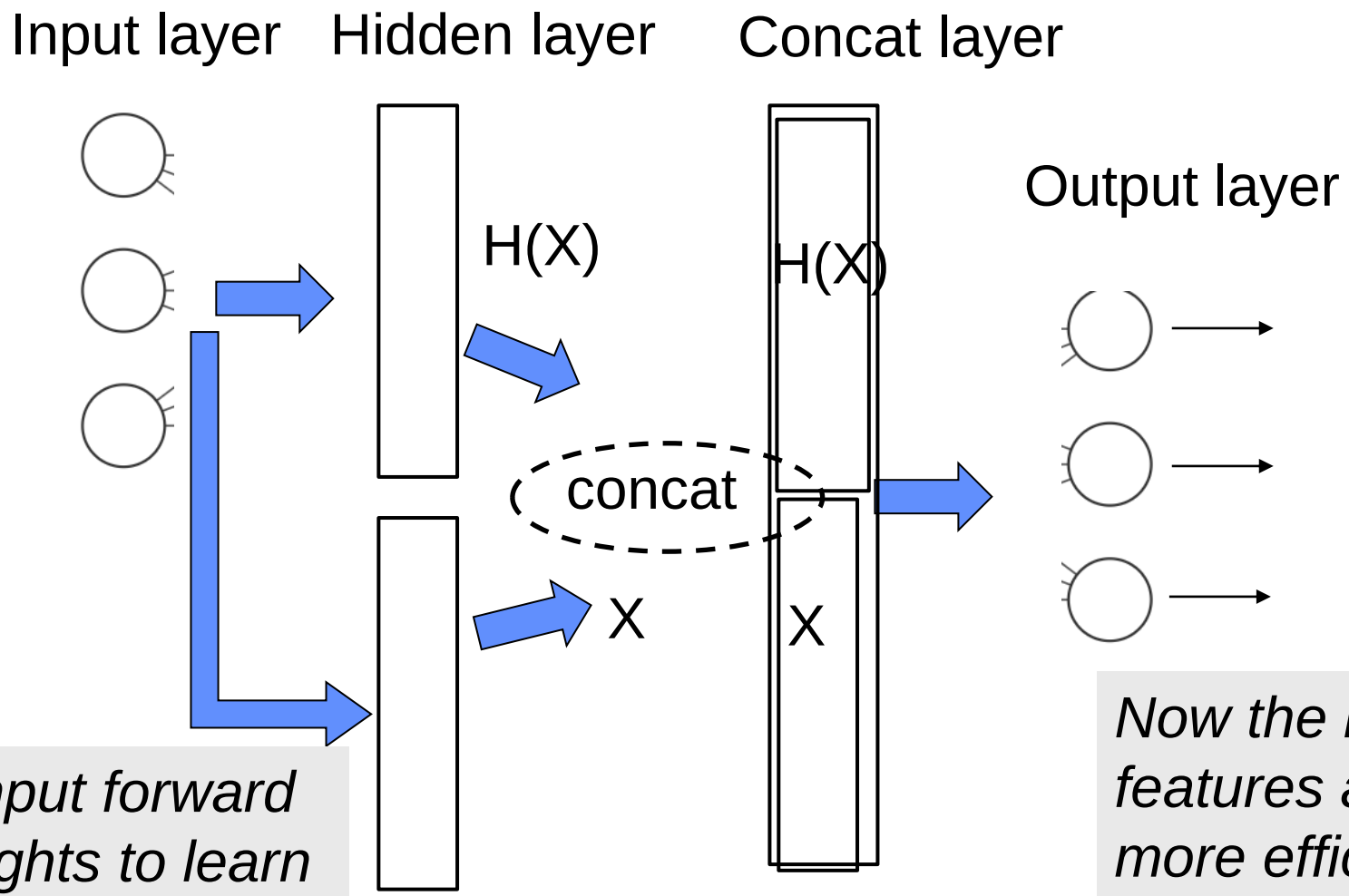


To help the MLP learn directly from input carry input forward



carry input forward

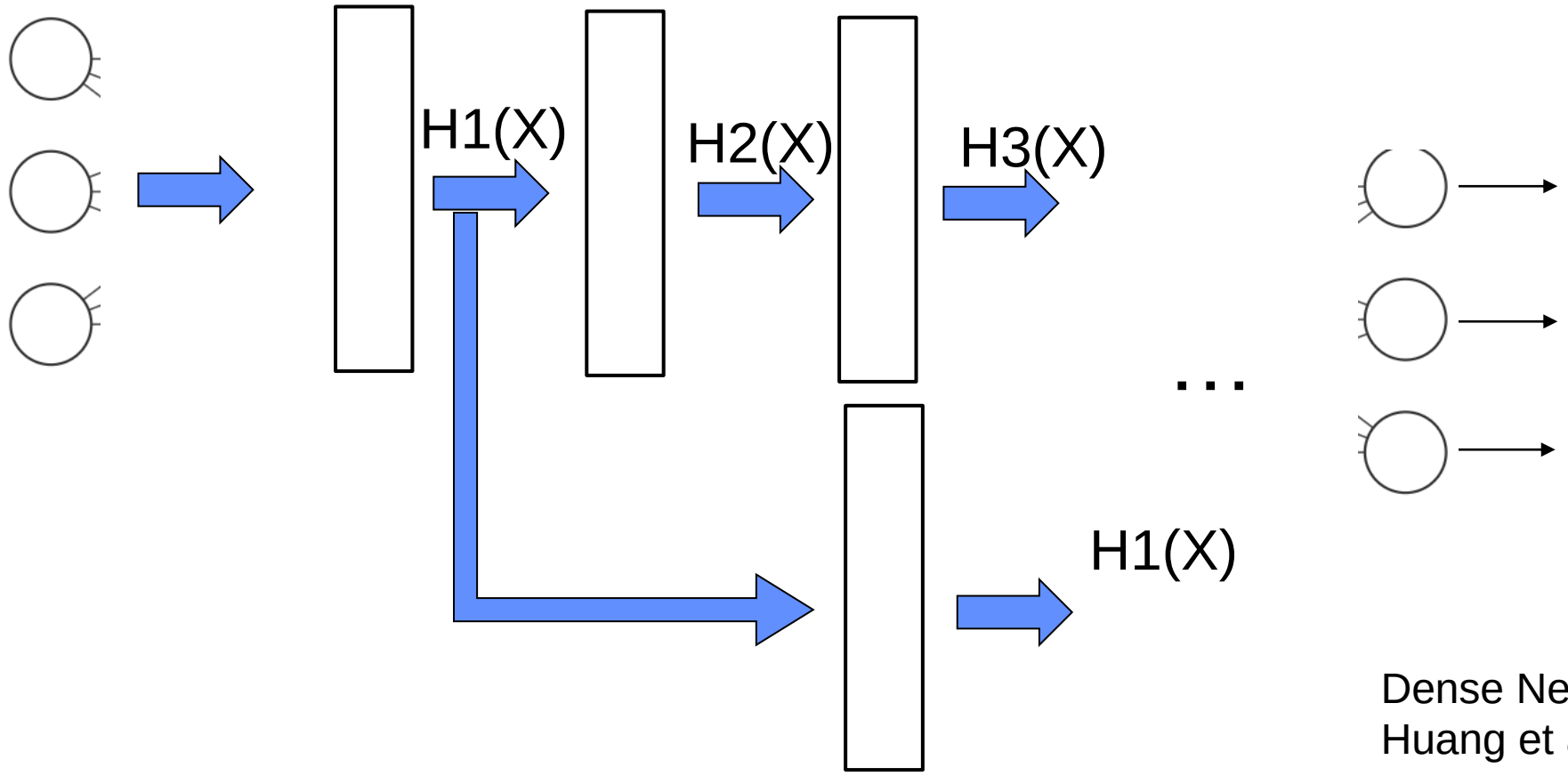
Concatenate input with hidden units into new layer



carry input forward
No weights to learn

Now the input features are used more efficiently

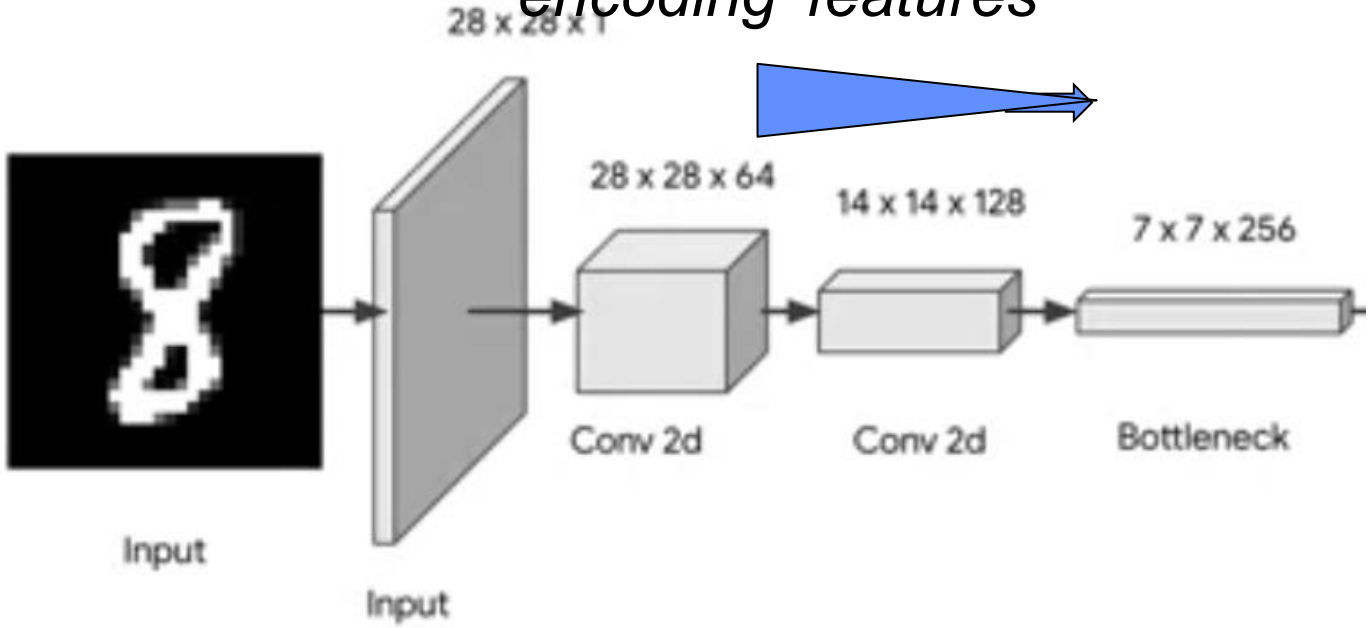
Can be done for any (or all) previous layer and *skip* any number of layers



Dense Nets
Huang et al

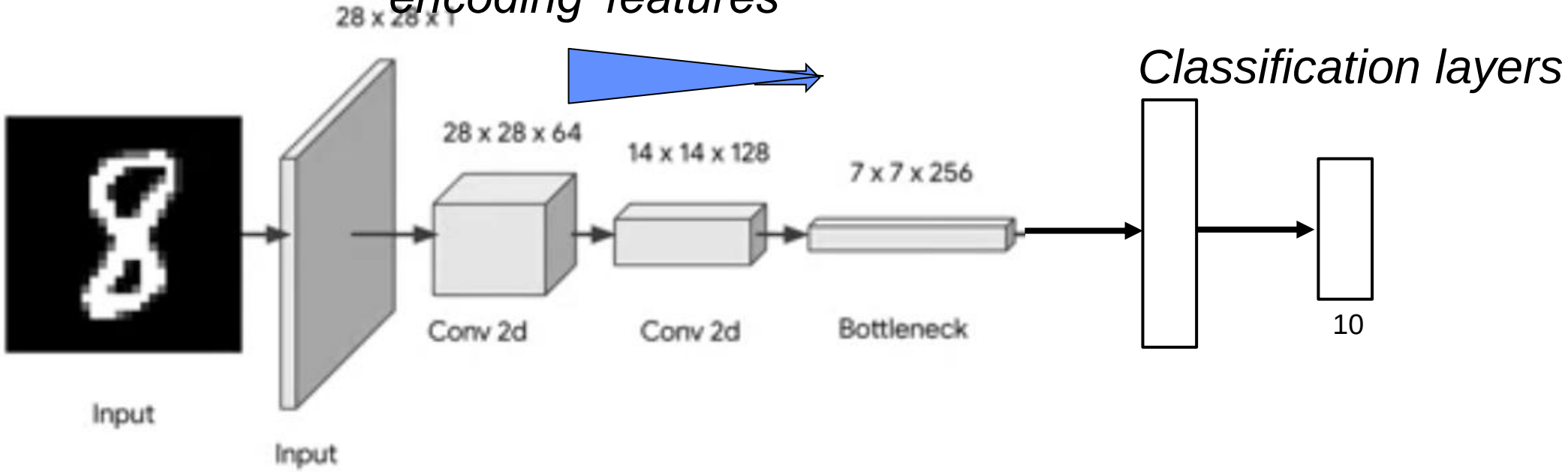
Recall: CNN architecture for MNIST classification

more feature maps & downsampling :
'encoding' features



Consider: CNN architecture for MNIST classification

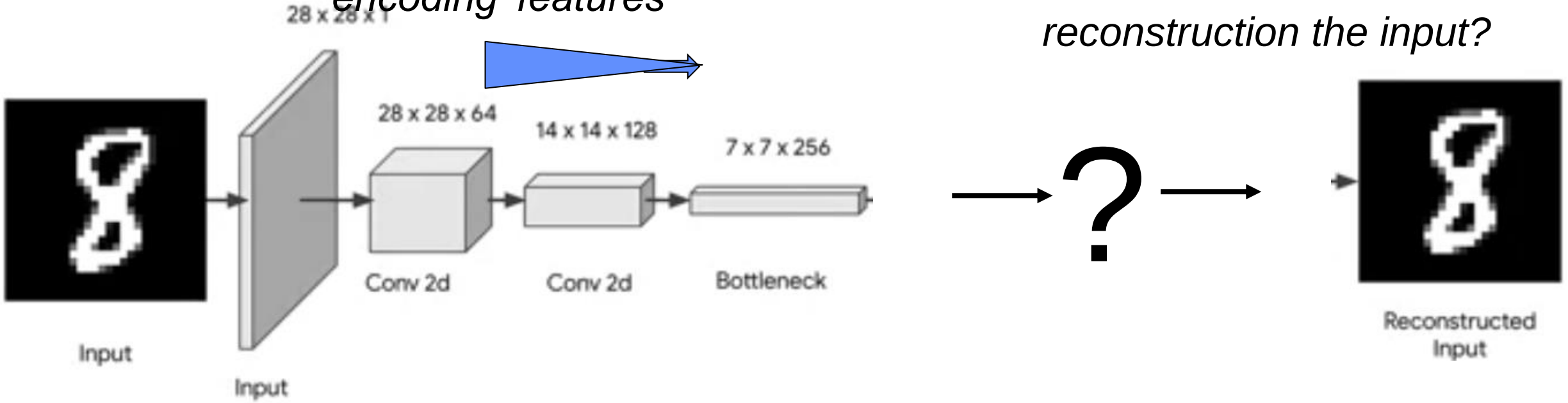
more feature maps & downsampling :
'encoding' features



A CNN architecture for MNIST autoencoding

more feature maps & downsampling : 'encoding' features

What if we want to reconstruction the input?



A CNN architecture for MNIST autoencoding

more feature maps & downsampling : 'encoding' features

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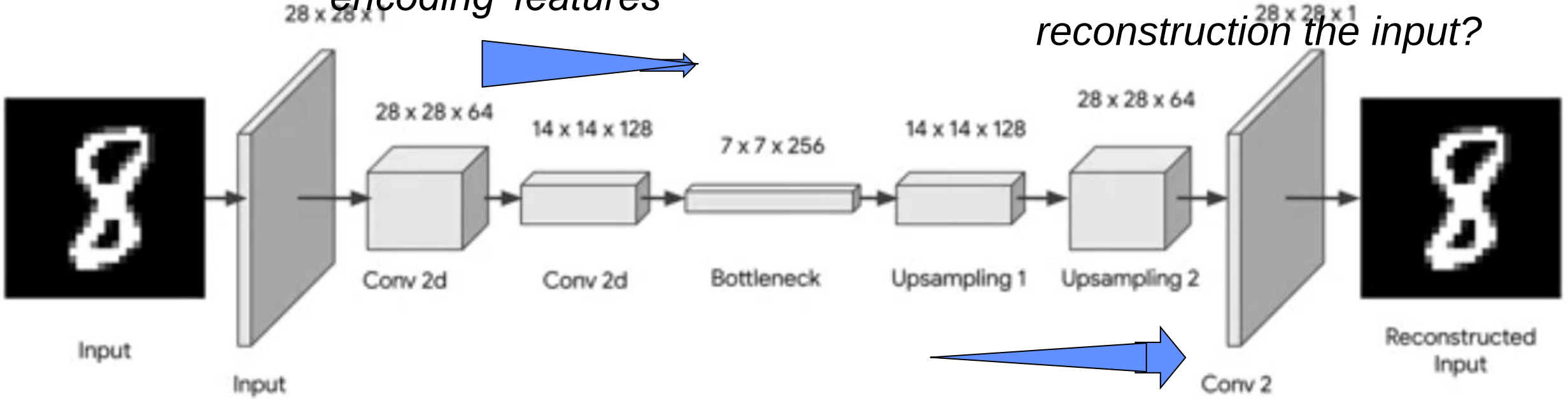
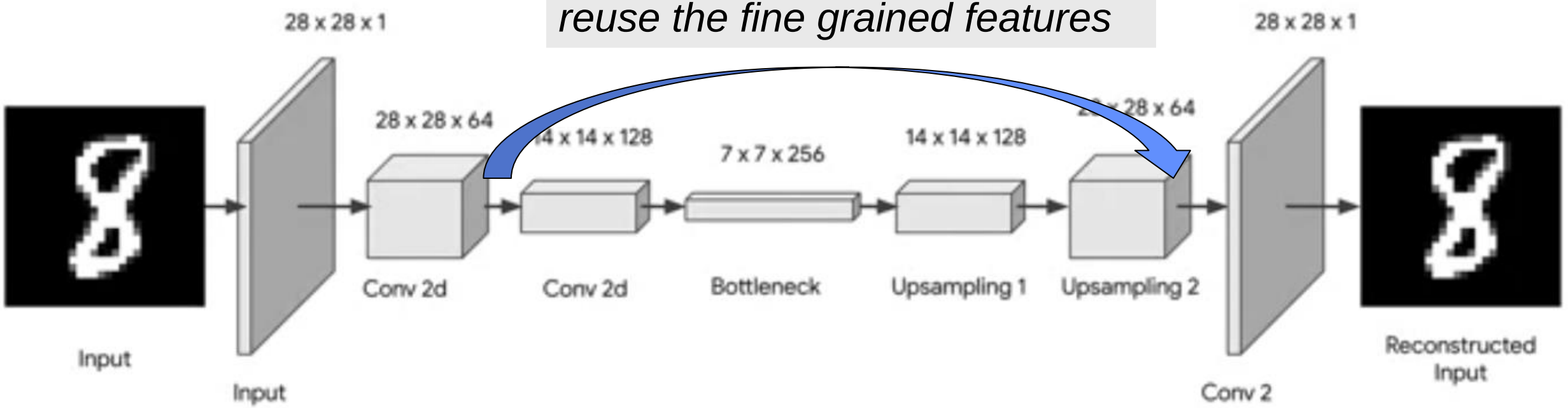


Use 'upsampling' to reverse the encoding – ie. decoding

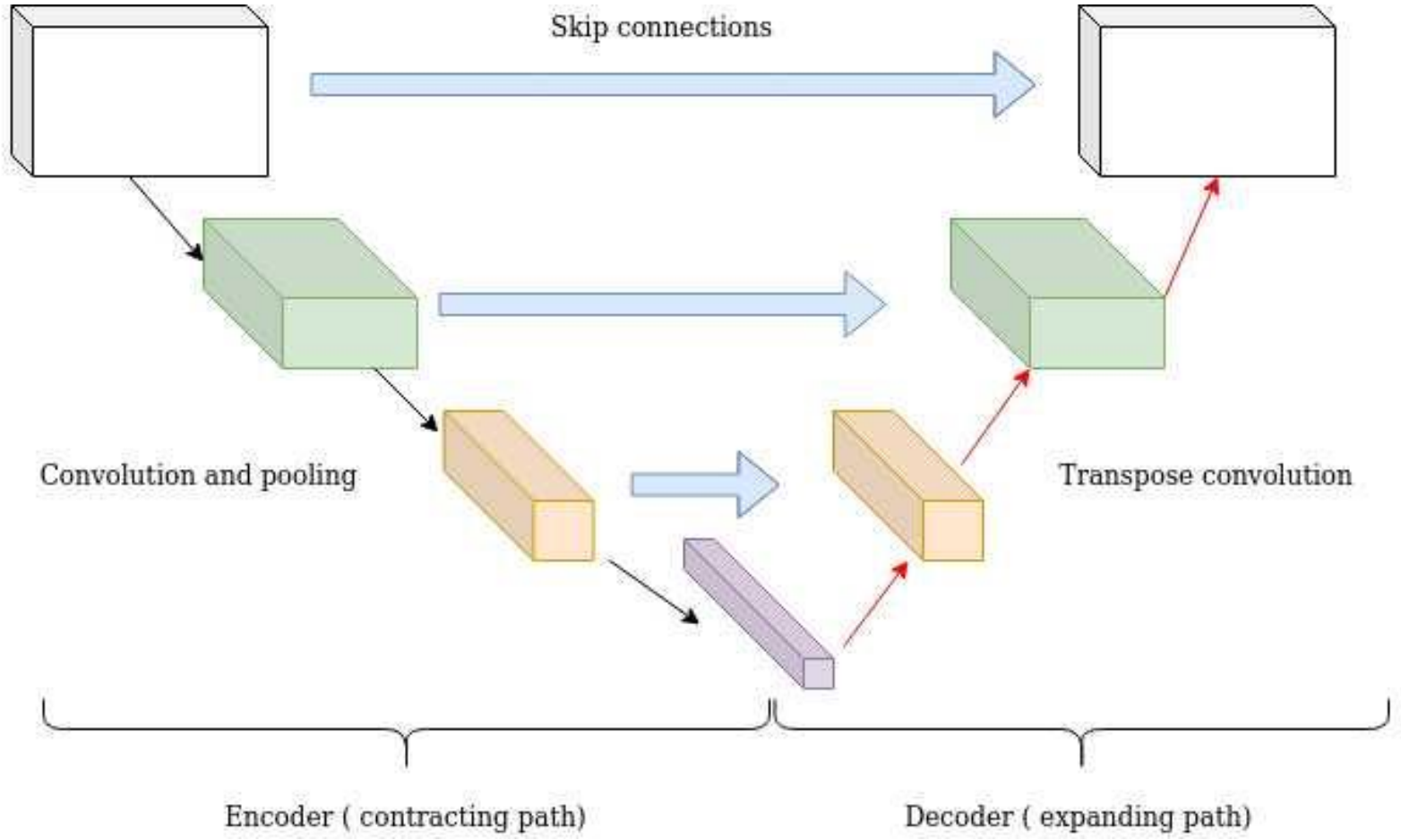
A CNN architecture for MNIST autoencoding

Adding skip connections helps reuse the fine grained features



NOTE the 28x28 encoded maps have to be skipped ahead to where the 28x28 decoding maps are – which axis is concatenated?

Image Encoder-Decoder is a “UNET” architecture



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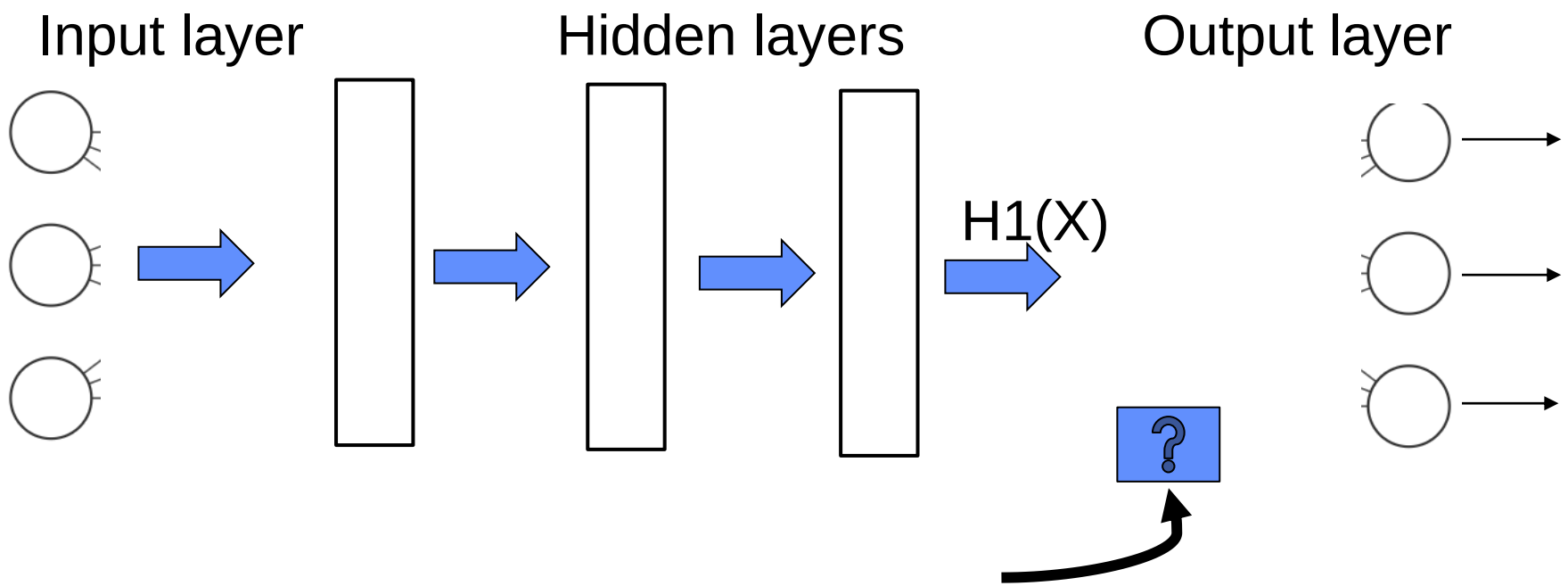
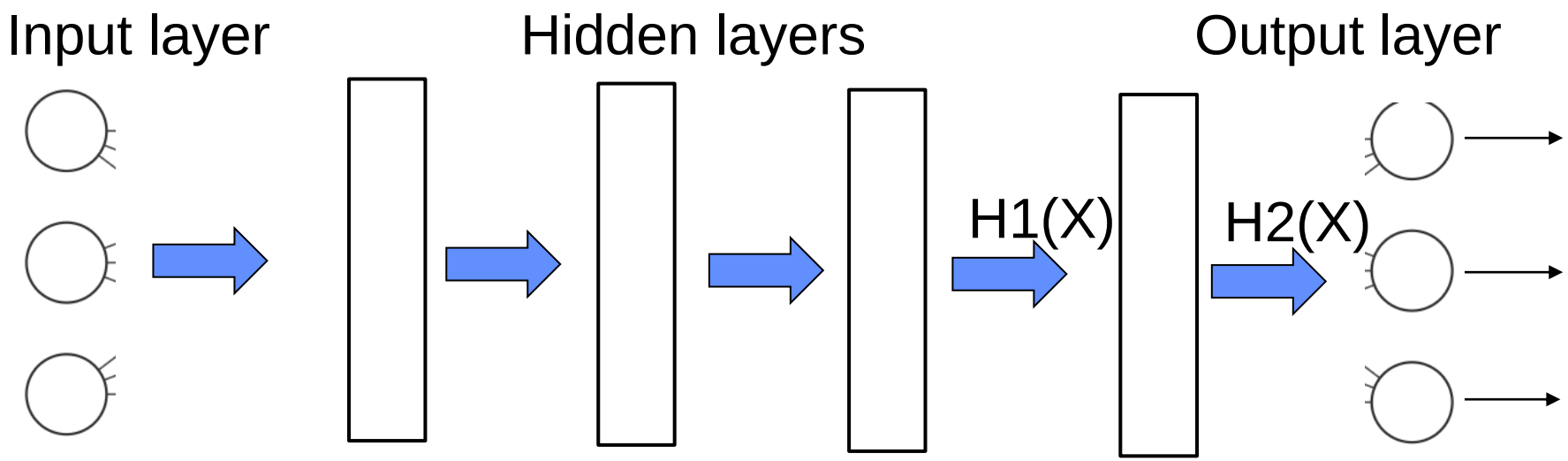
Consider: Can we keep adding deep layers?



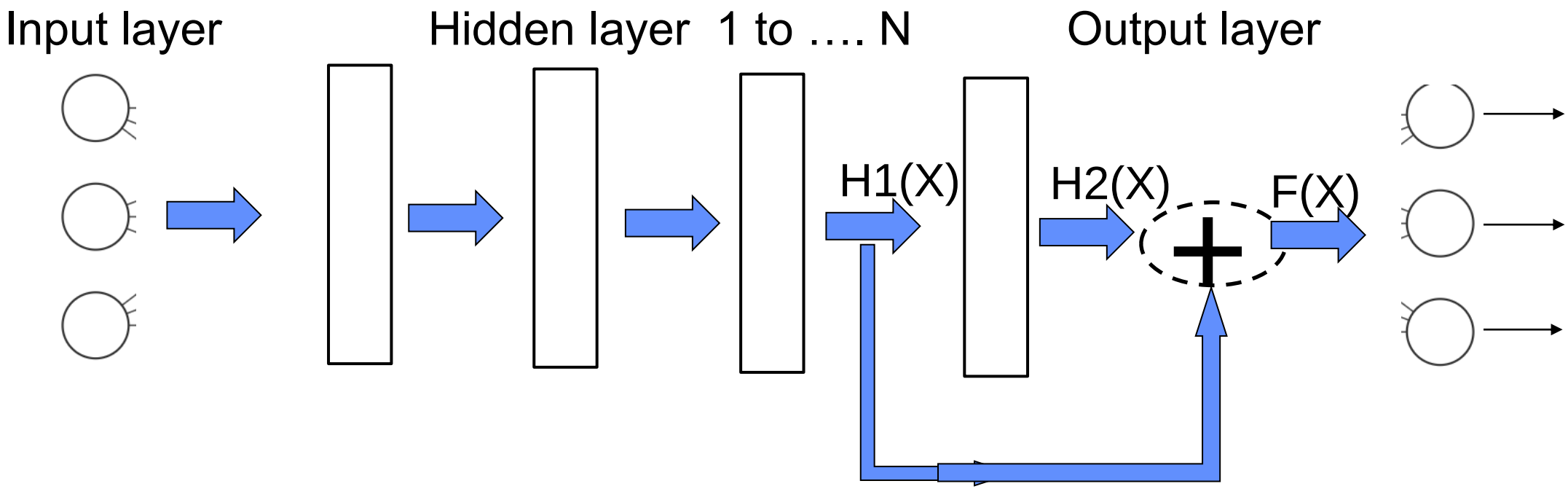
Given some deep network,
should I add another layer?
What should a new layer learn?

Consider: Can we keep adding deep layers?



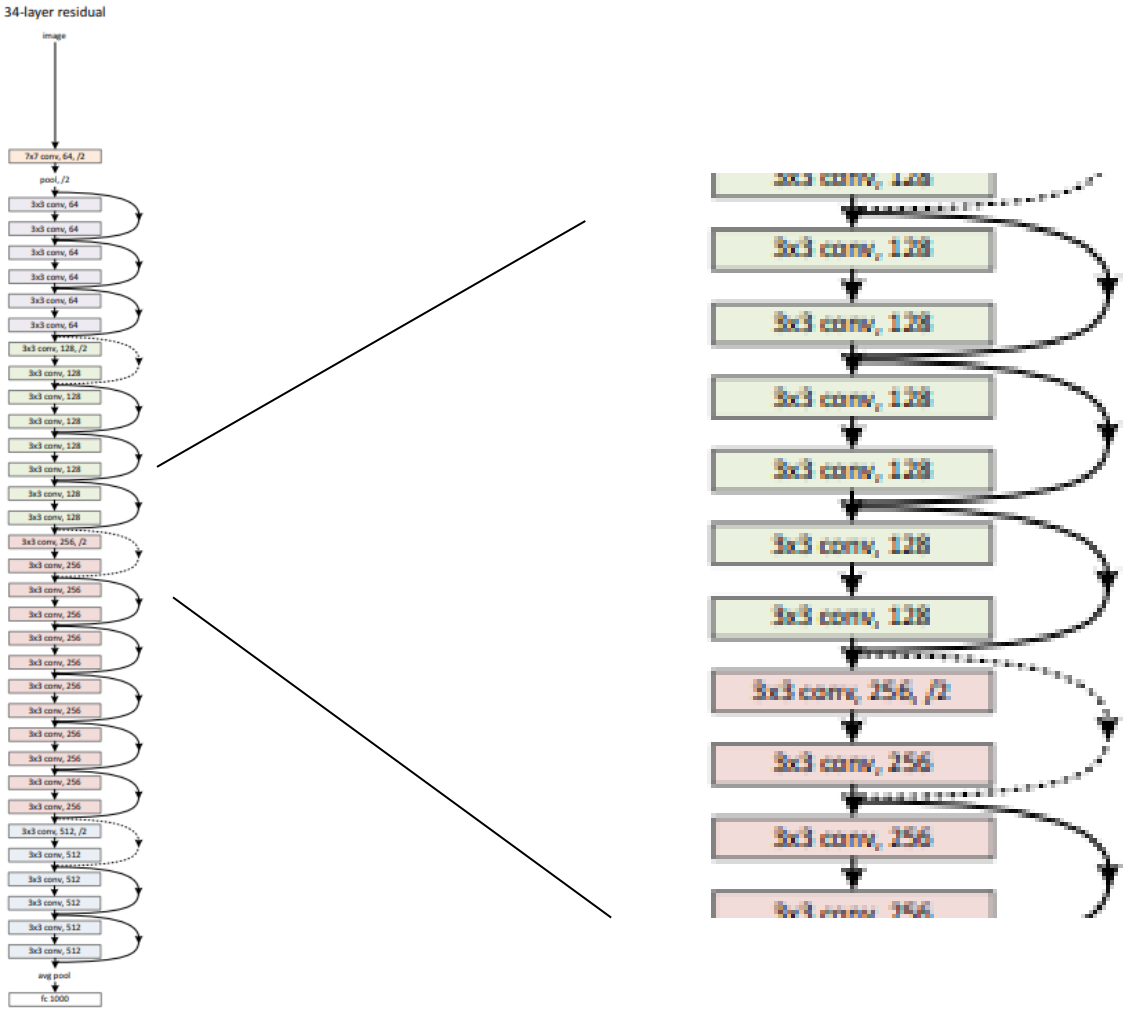
If H1(X) is good then this new layer could be unnecessary,
Eg H2(X) should be just H1(X)

Skip with addition makes a ‘residual’ connection



Make it easy for next layer to learn nothing –
e.g. use F(X)=H2(X)+H1(X) so that H2(X)=F(X)-H1(X) .
The H2() function learned is a residual function

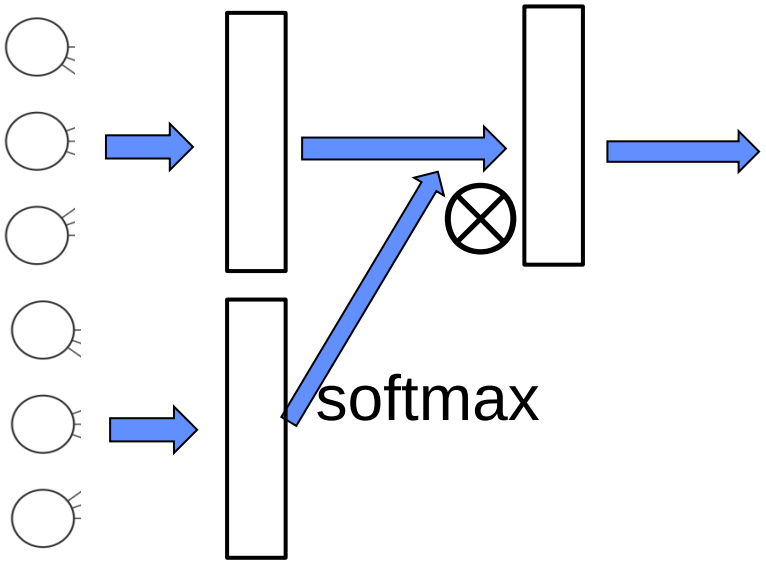
“Resnet” residual connections help deeper learning



Deep Residual Learning, He et.al, 2015

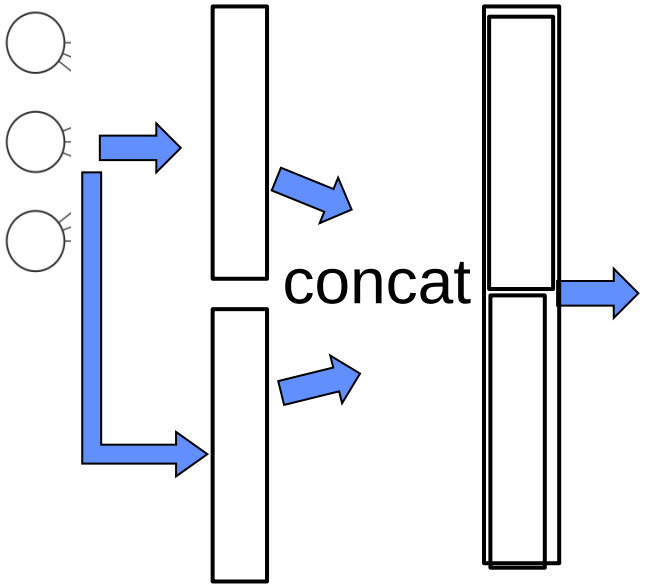
Summary: useful connections for architectures, and the intuitions

Softmax for gating



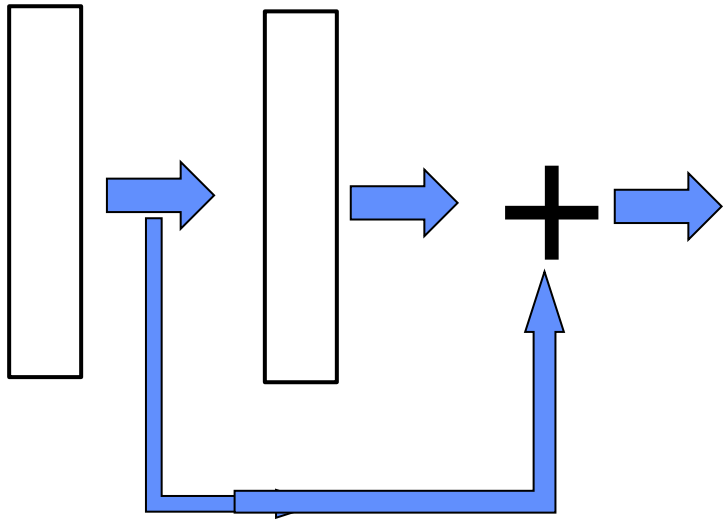
Recurrent nets,
language transformer nets

Skip connections
for feature reuse



UNET, also
feedforward nets..

Residual connections
help deeper learning



Resnet, large image
classification

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Keras: Sequential API VS Functional API

```
#specify the neural network model and learning parameters
my_model  = tf.keras.models.Sequential([
                    tf.keras.layers.Flatten(input_shape=(28, 28)),
                    tf.keras.layers.Dense(32,activation='relu'),
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my_model.summary()
```

A sequence of layers: the inputs are assumed to be in order

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inputs_flattened    = tf.keras.layers.Flatten()(inputs)
hidden_layer        = tf.keras.layers.Dense(32,activation='relu')(inputs_flattened)
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A sequence of functions: Input layer(s) are specified

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my_model = tf.keras.Model(inputs,output_layer)
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```

A sequence of functions: Input layer(s) are specified

The Model() function figures out the full path(s) to connect the input(s) to output(s)

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Exercise

- MNIST autoencoder, reconstruct digits from noisy inputs
- Add skip connections with concatenation

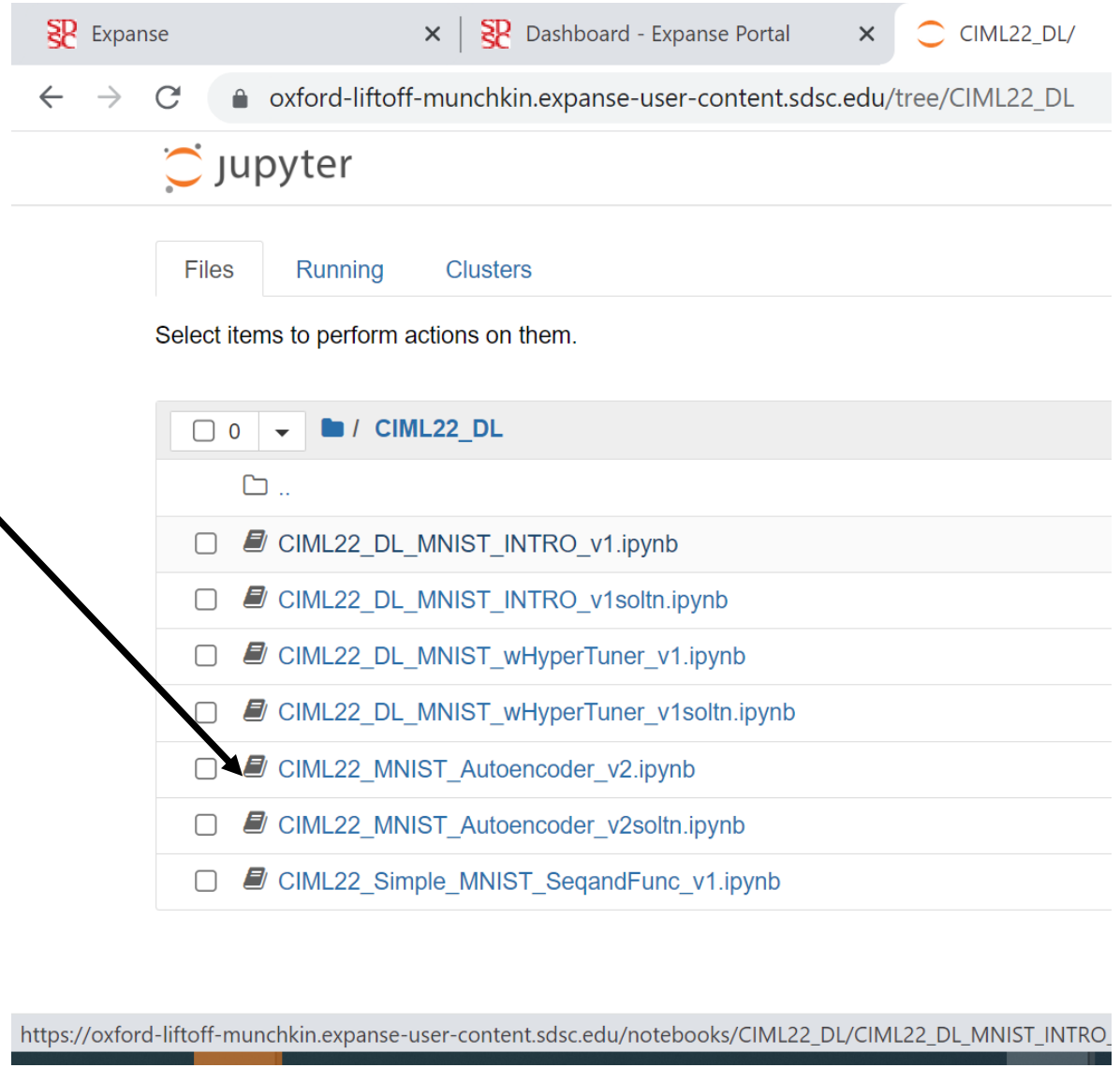
Note: make sure you see how the outputs from encoding layers are matched up to inputs for decoding layers!

14x14 encoding feature maps should be concatenated with 14x14 decoding maps

- Review outputs to see improvements

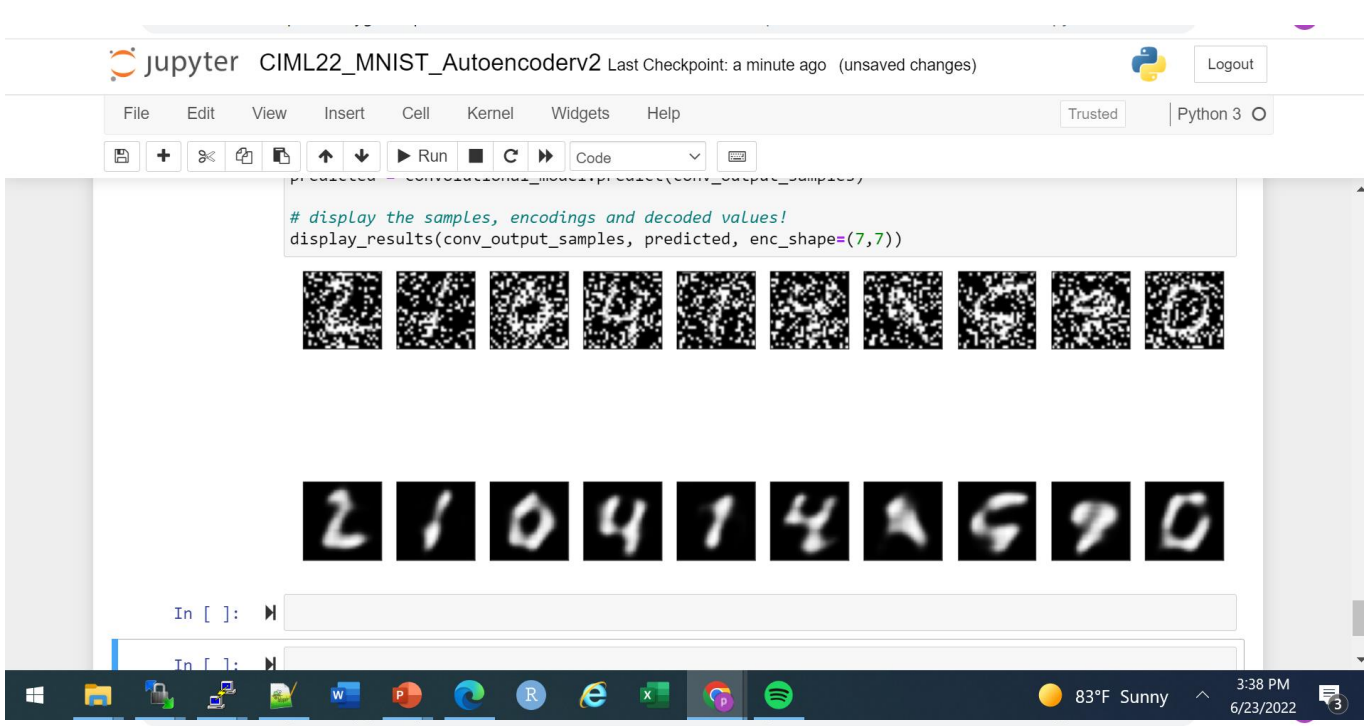
In jupyter notebook session open the MNIST_Autoencoder notebook

Follow instructions in the notebook

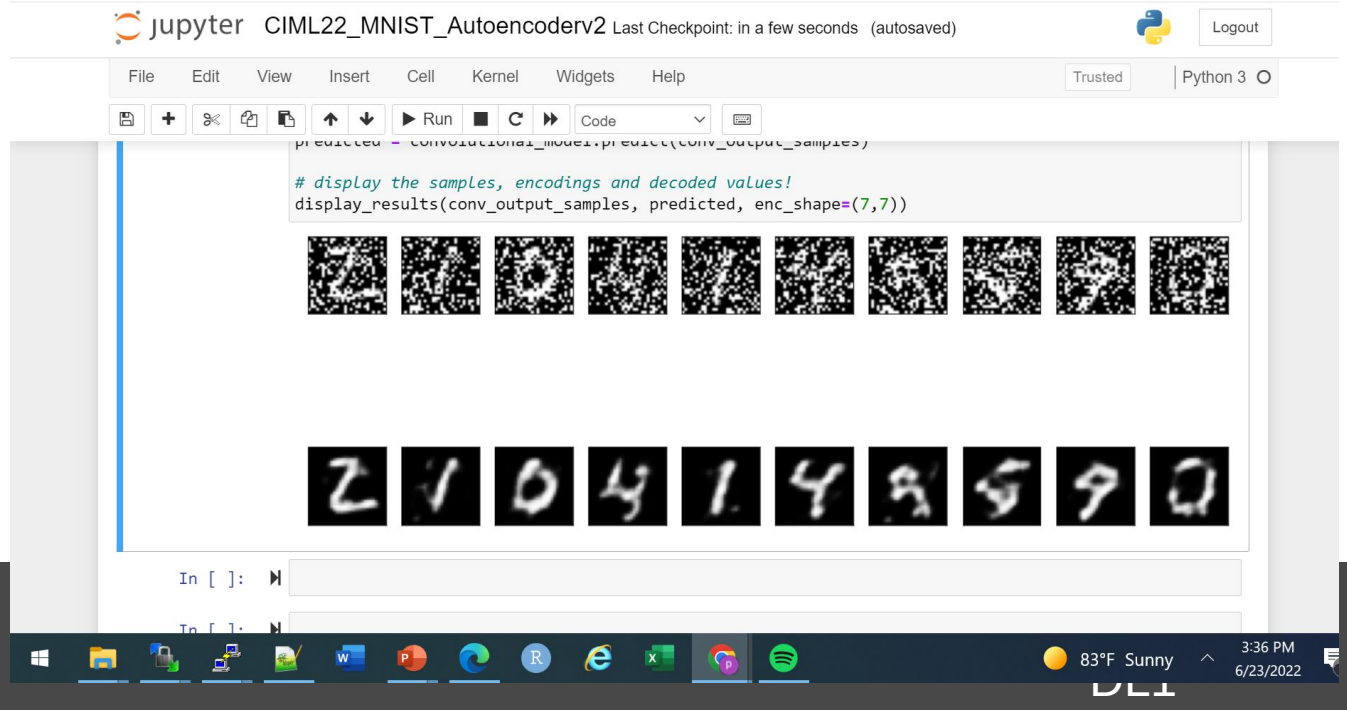


```python
def encoder(inputs):
  '''Defines the encoder with two Conv2D and max pooling layers.'''
  conv_1 = tf.keras.layers.Conv2D(filters=64, kernel_size=(3,3), activation='relu', padding='same')(inputs)
                                                                  #padding same produces same output size
  max_pool_1 = tf.keras.layers.MaxPooling2D(pool_size=(2,2))(conv_1) #max pooling does the downsampling

  conv_2 = tf.keras.layers.Conv2D(filters=128, kernel_size=(3,3), activation='relu', padding='same')(max_pool_1)
  max_pool_2 = tf.keras.layers.MaxPooling2D(pool_size=(2,2))(conv_2)

  return max_pool_2, conv_1, conv_2
```

```python
def decoder(inputs, enc_conv1,enc_conv2):
  '''Defines the decoder path to upsample back to the original image size.'''
  #Notice that padding = same keeps the output same size as input

  conv_1      = tf.keras.layers.Conv2D(filters=128, kernel_size=(3,3), activation='relu', padding='
  up_sample_1 = tf.keras.layers.UpSampling2D(size=(2,2))(conv_1)

#another optoin is transpose
# up_sample_1 = tf.keras.layers.Conv2DTranspose(128,kernel_size=(2,2),strides=(2,2))(conv_1)
# in a transpose convolutional layer,

  # --------->>>>> before the conv_2 line add a
  # --------->>>>       tf.keras.layers.concatenate statement to combine enc_conv2 with decoding u
  #  conv_2      = tf.keras.layers.Conv2D(filters=64, kernel_size=(3,3), activation='relu', padding

  skip_concat_1 = tf.keras.layers.concatenate([up_sample_1, enc_conv2])
  conv_2      = tf.keras.layers.Conv2D(filters=64, kernel_size=(3,3), activation='relu', padding='s
                                  # ---------->>>> and change the input into conv_2
```



With out skip
20 epochs
Loss 0.1664



With skip,
20 epochs loss 0.14

Are the numbers a little bit more reconstructed?