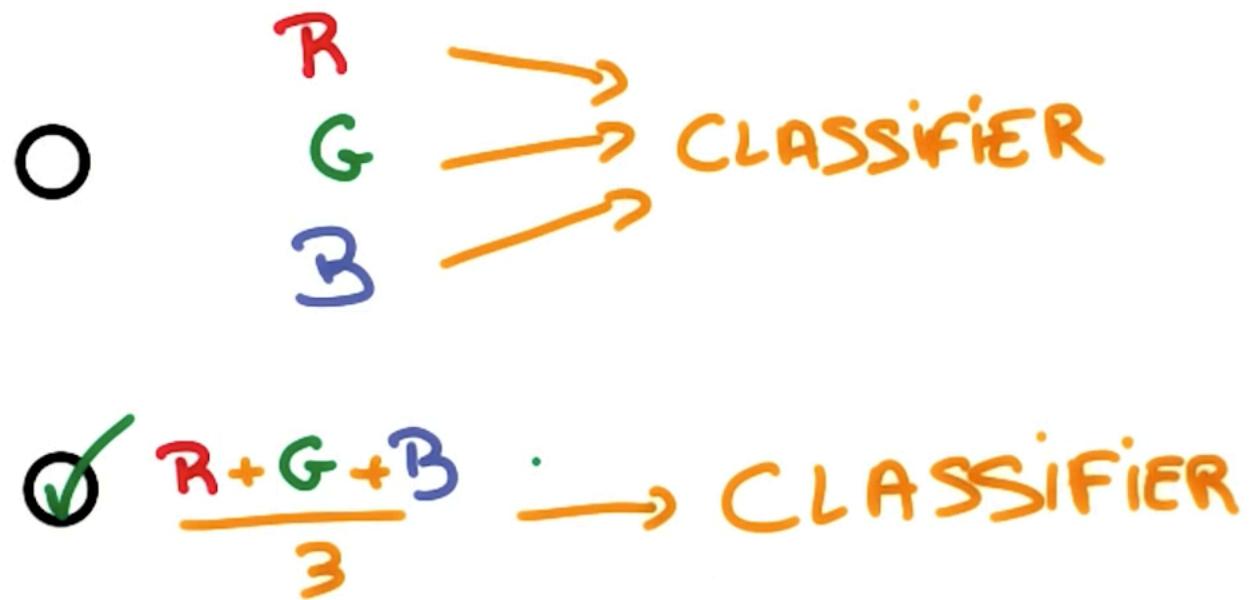
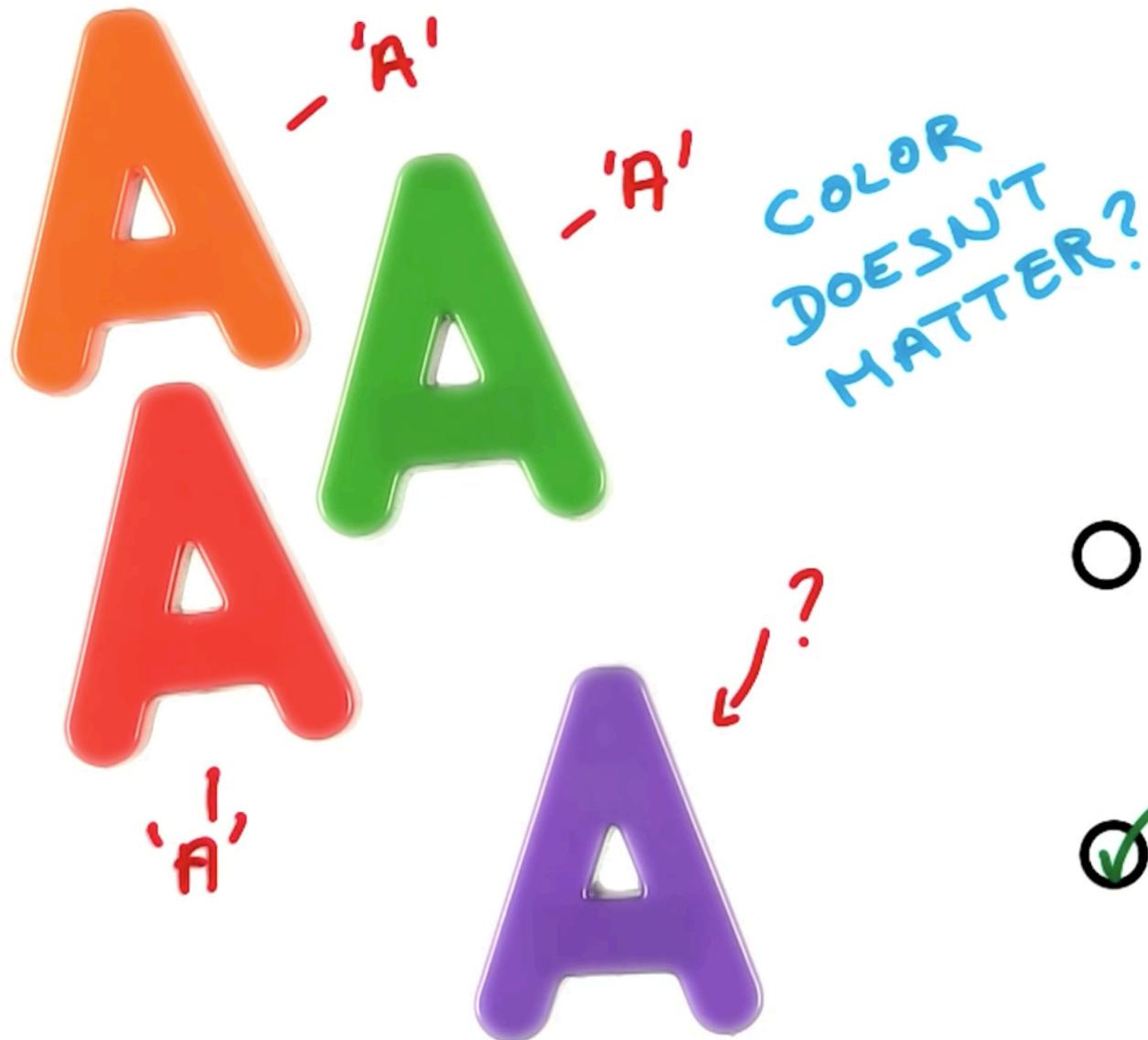


STRUCTURE      HELPS      LEARNING





# TRANSLATION INVARIANCE →



BLAH BLAH BLAH KITTEN BLAH BLAH

BLAH KITTEN BLAH.

KITTEN BLAH BLAH BLAH BLAH BLAH BLAH

BLAH BLAH BLAH BLAH BLAH KITTEN BLAH

A blue curved arrow starts from the first 'KITTEN' in the second row and points to the second 'KITTEN' in the fourth row. Below this arrow, the words 'SAME ENTITY' are written in blue capital letters.

SAME  
ENTITY

R       $w_1$   
G       $w_1$   
B       $w_1$



$w_2$   
 $w_2$



BLAH BLAH BLAH KITTEN BLAH BLAH  
BLAH KITTEN BLAH.  
KITTEN BLAH BLAH BLAH BLAH BLAH  
BLAH BLAH BLAH BLAH BLAH KITTEN BLAH  
 $w_3$      $w_3$      $w_3$   
 $w_3$

WEIGHT  
SHARING

'STATISTICAL INVARIANTS'

'CONVNETS'

CONVOLUTIONAL  
NETWORKS

SAME  
 $w$



$w$



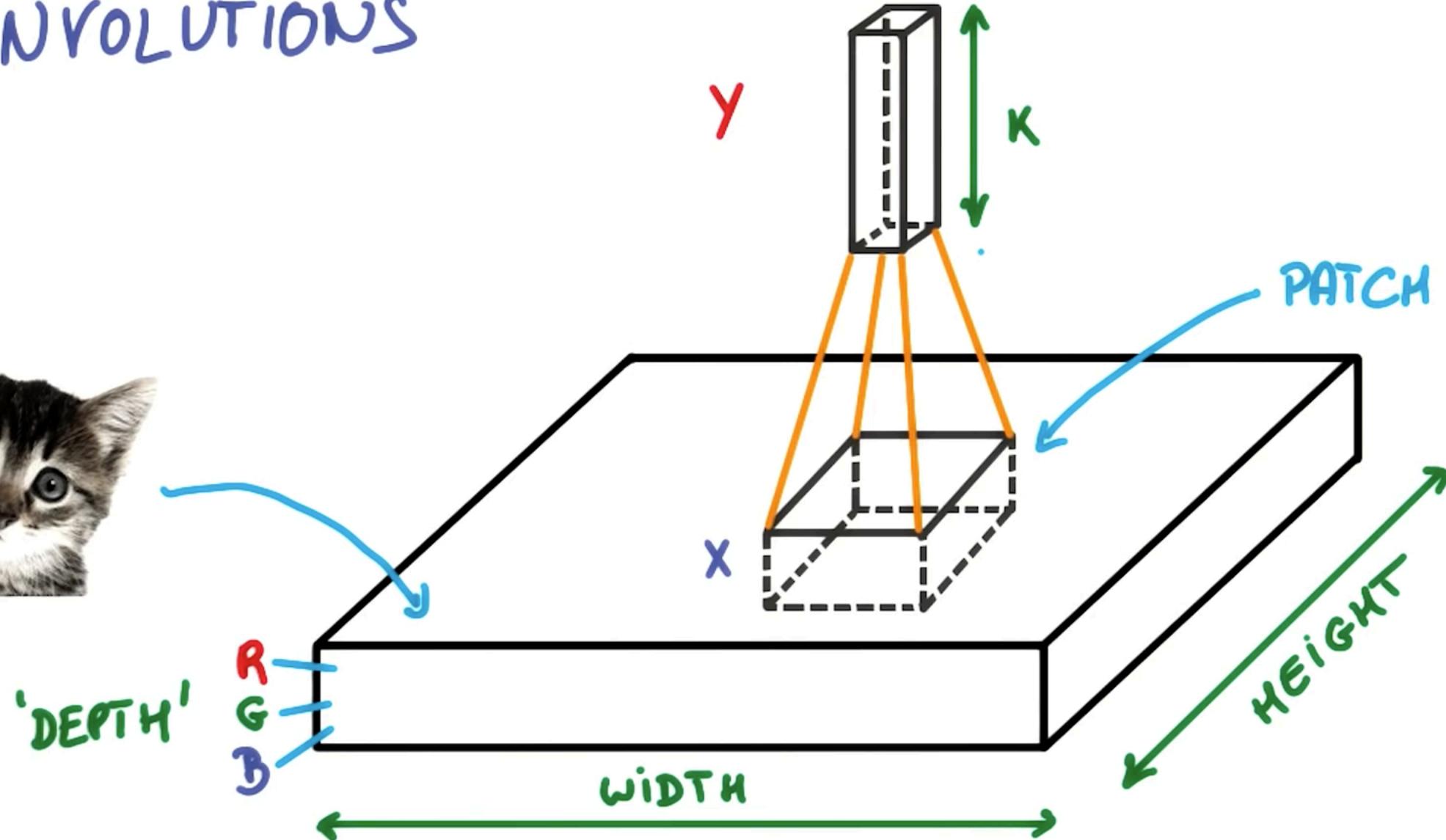
$w$



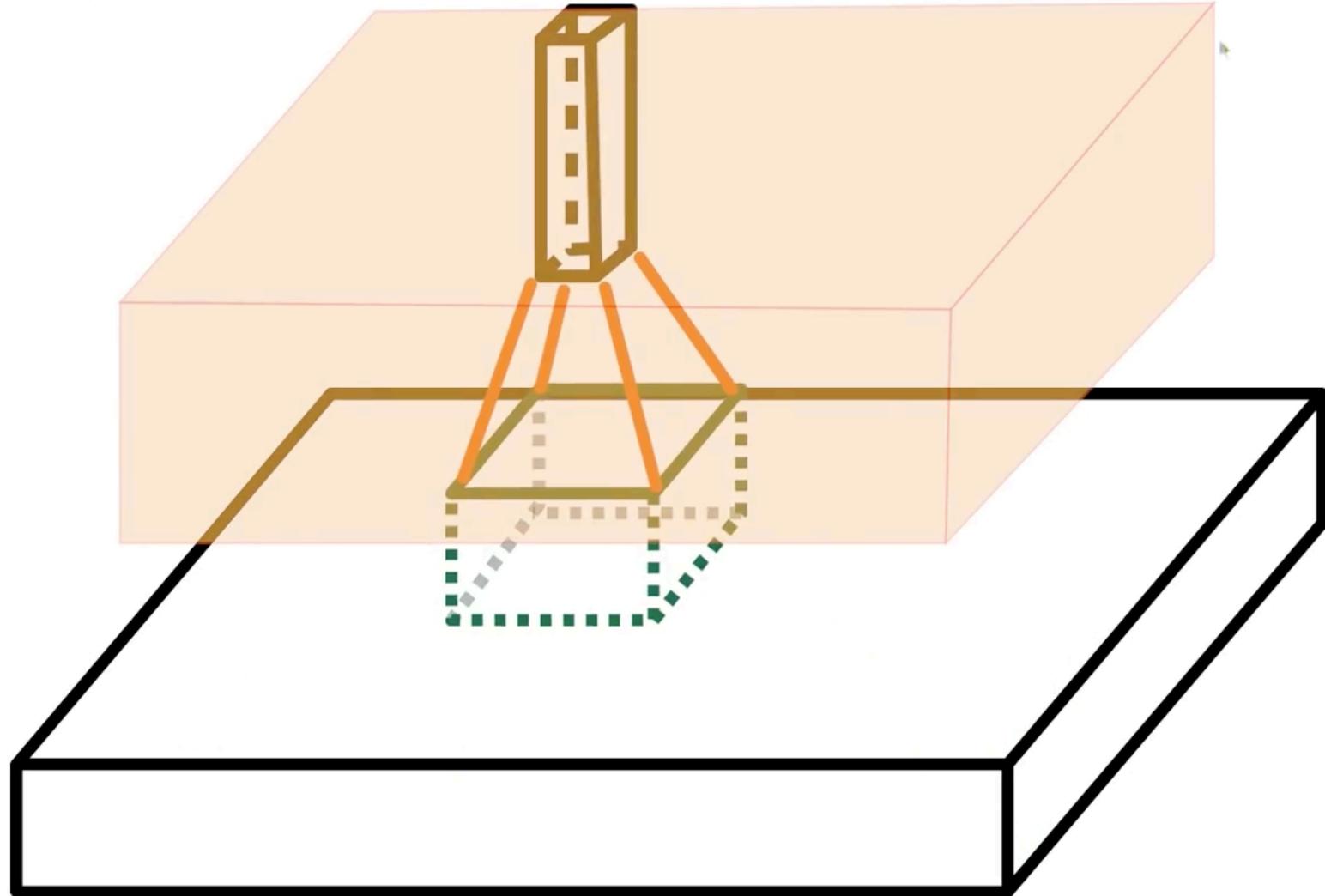
SAME  
 $w$   
AGAIN



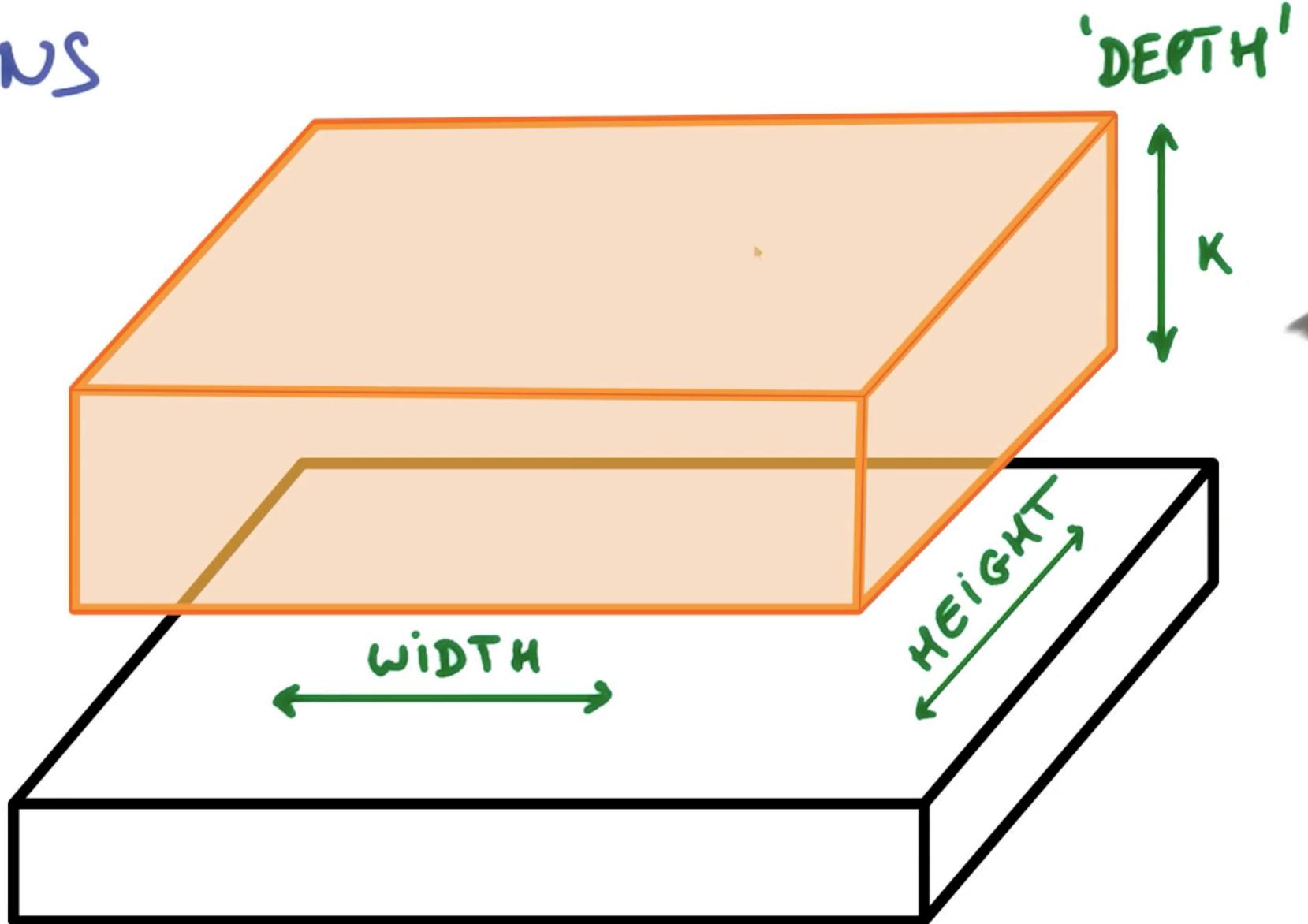
# CONVOLUTIONS



# CONVOLUTIONS



# CONVOLUTIONS



# CONVOLUTIONS



'DEPTH'

R

G

B

WIDTH

y

x

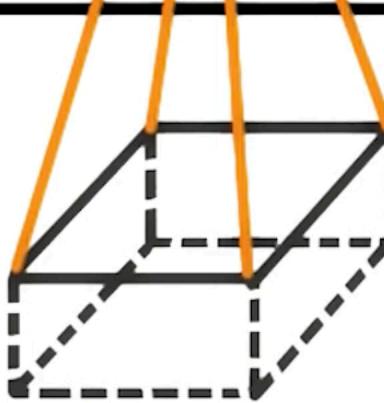


k

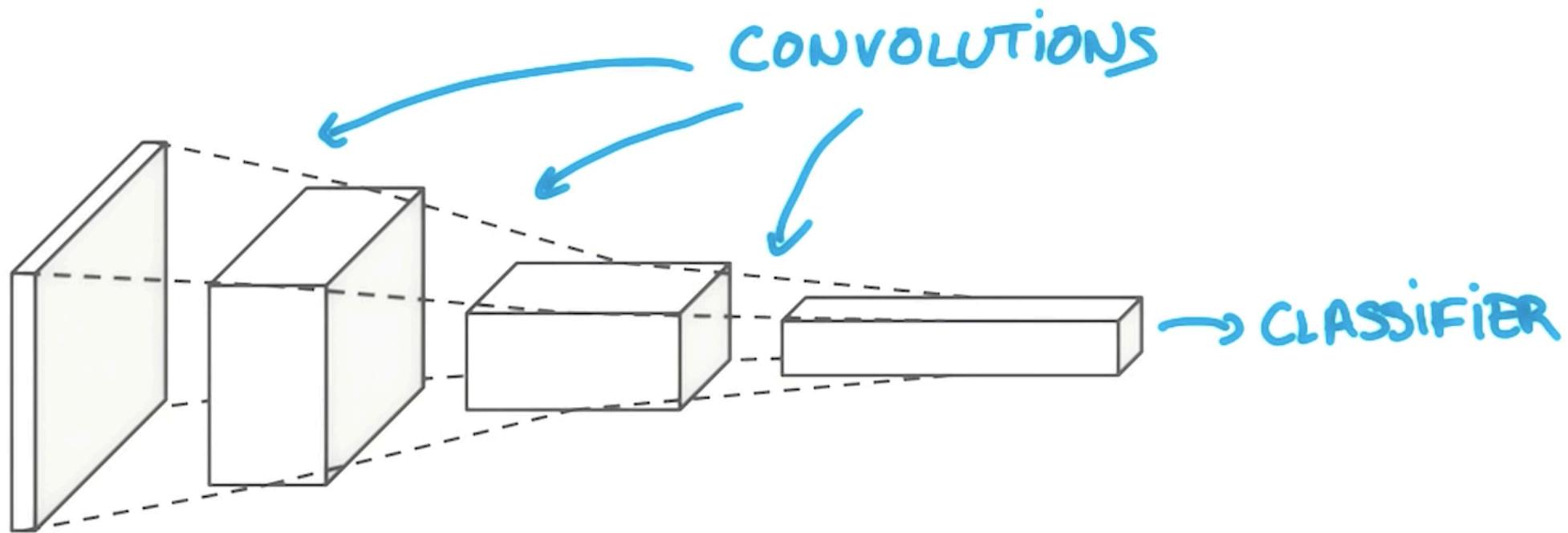
PATCH

HEIGHT

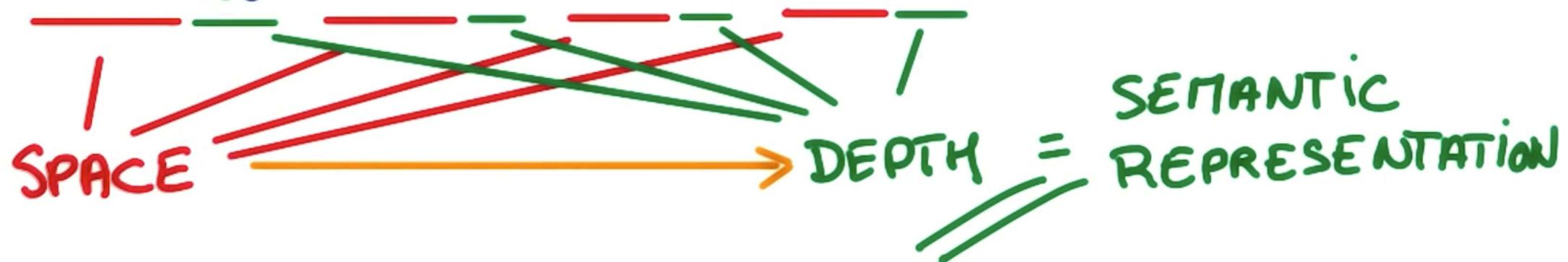
↑



# CONVOLUTIONAL PYRAMID

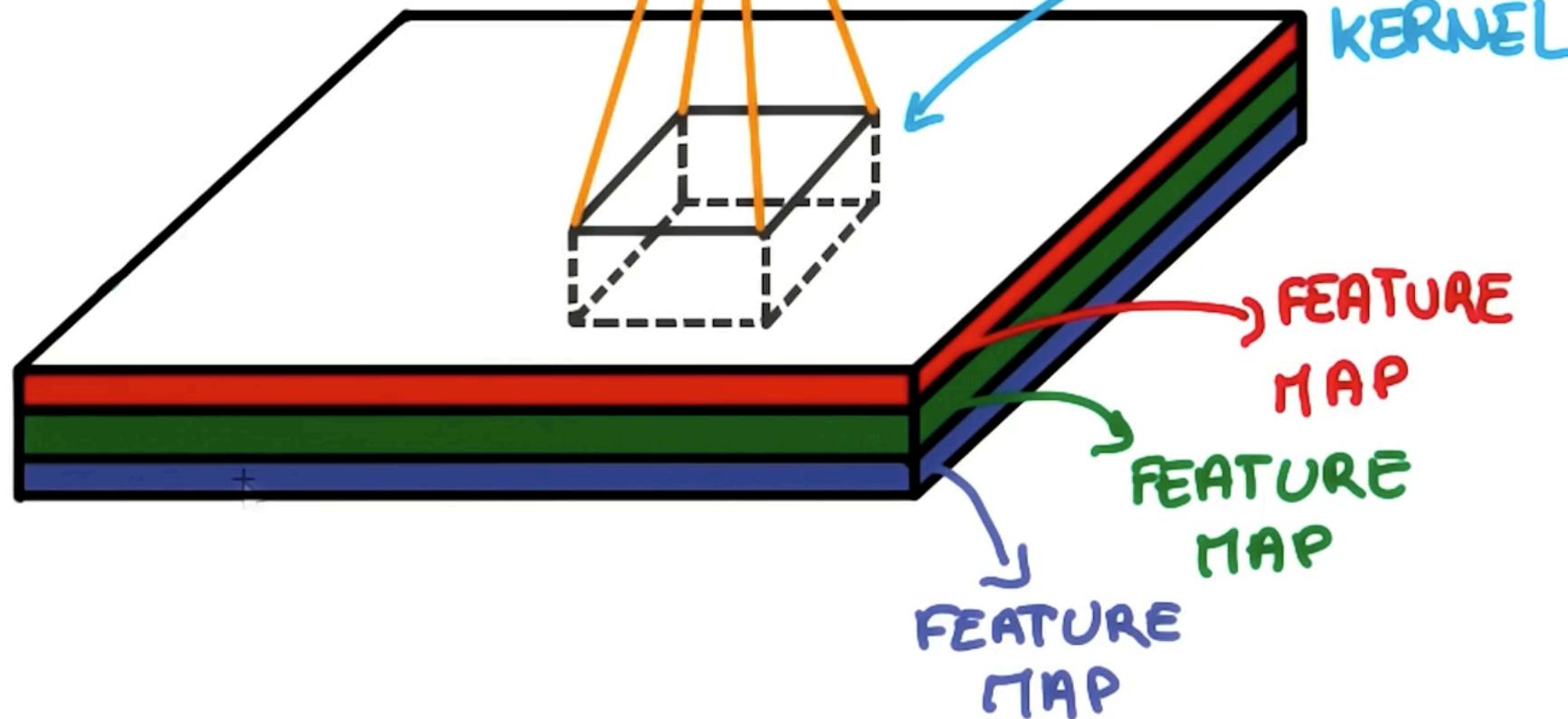


256x256 **RGB** → 128x128x16 → 64x64x64 → 32x32x256 ...

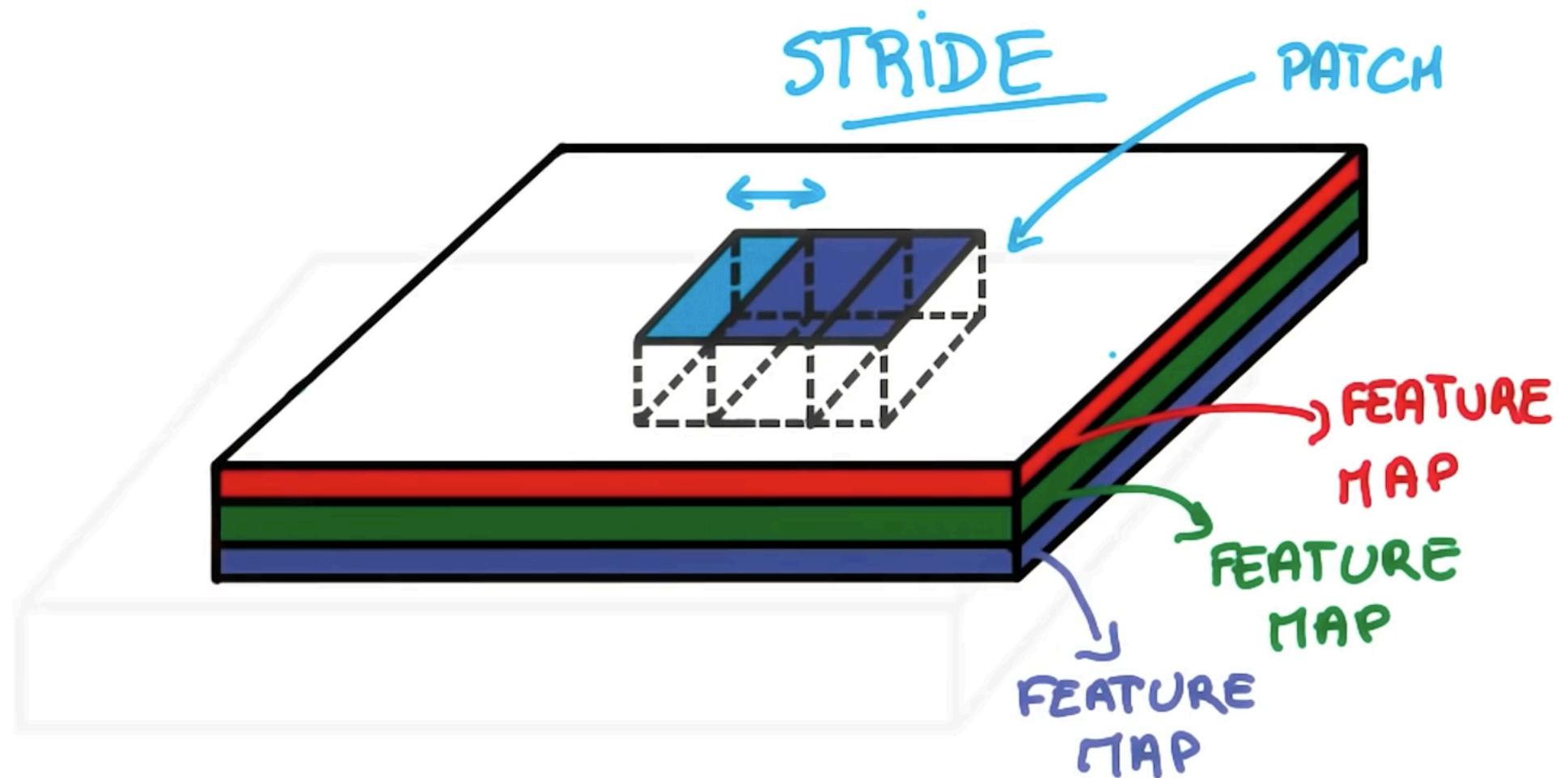


# CONVOLUTIONAL LINGO

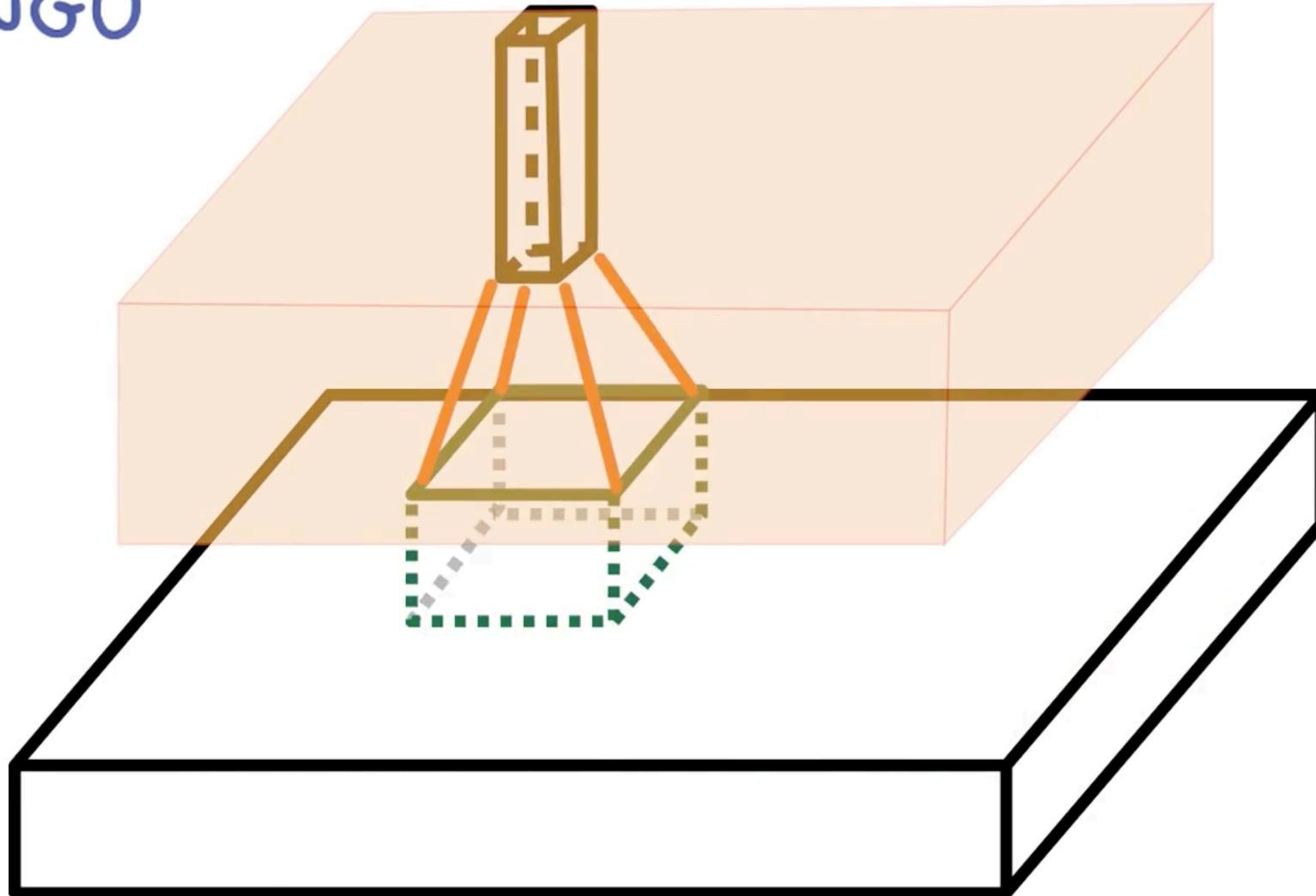
INPUT  
DEPTH



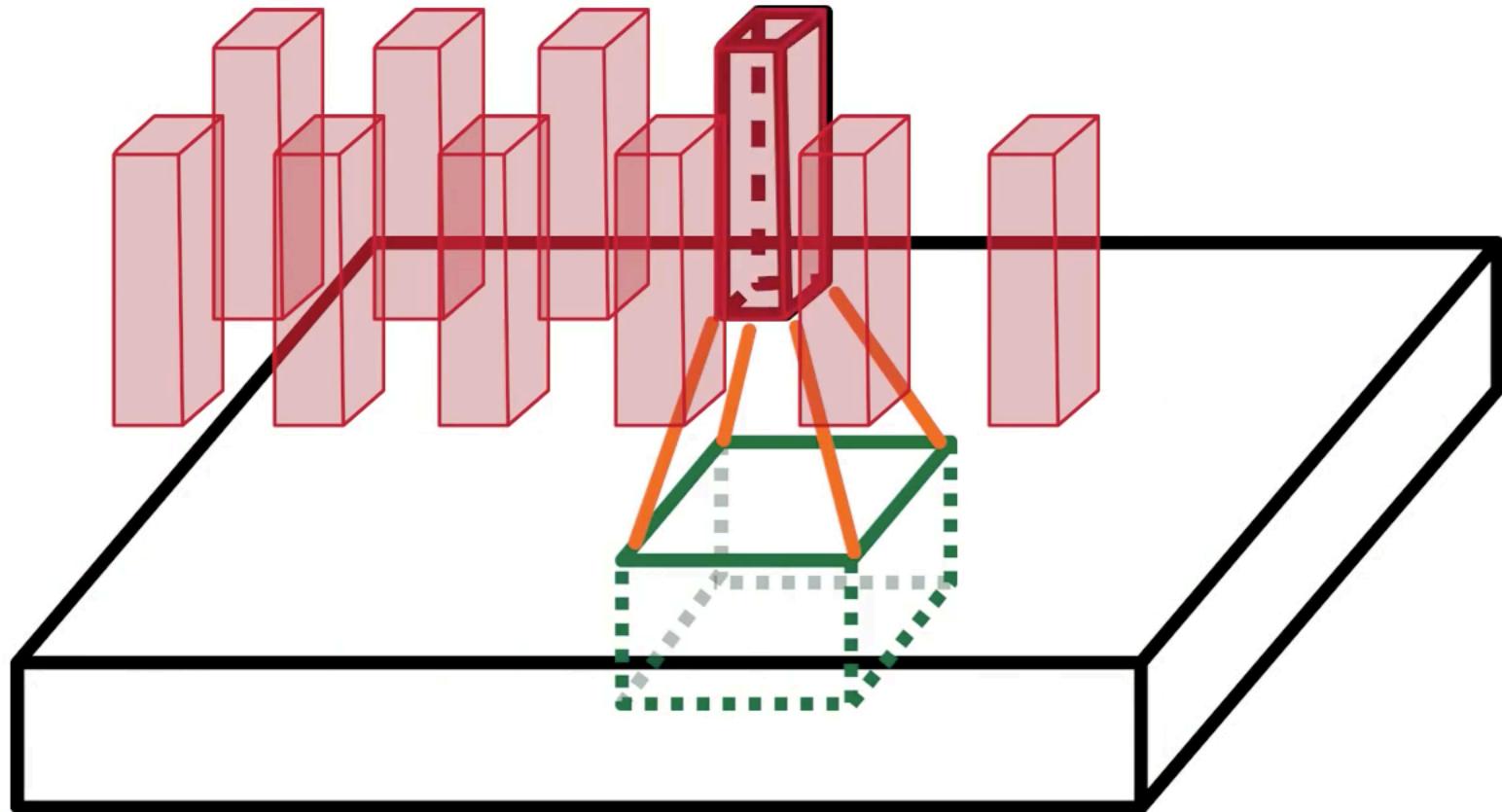
# CONVOLUTIONAL LINGO



# CONVOLUTIONAL LINGO

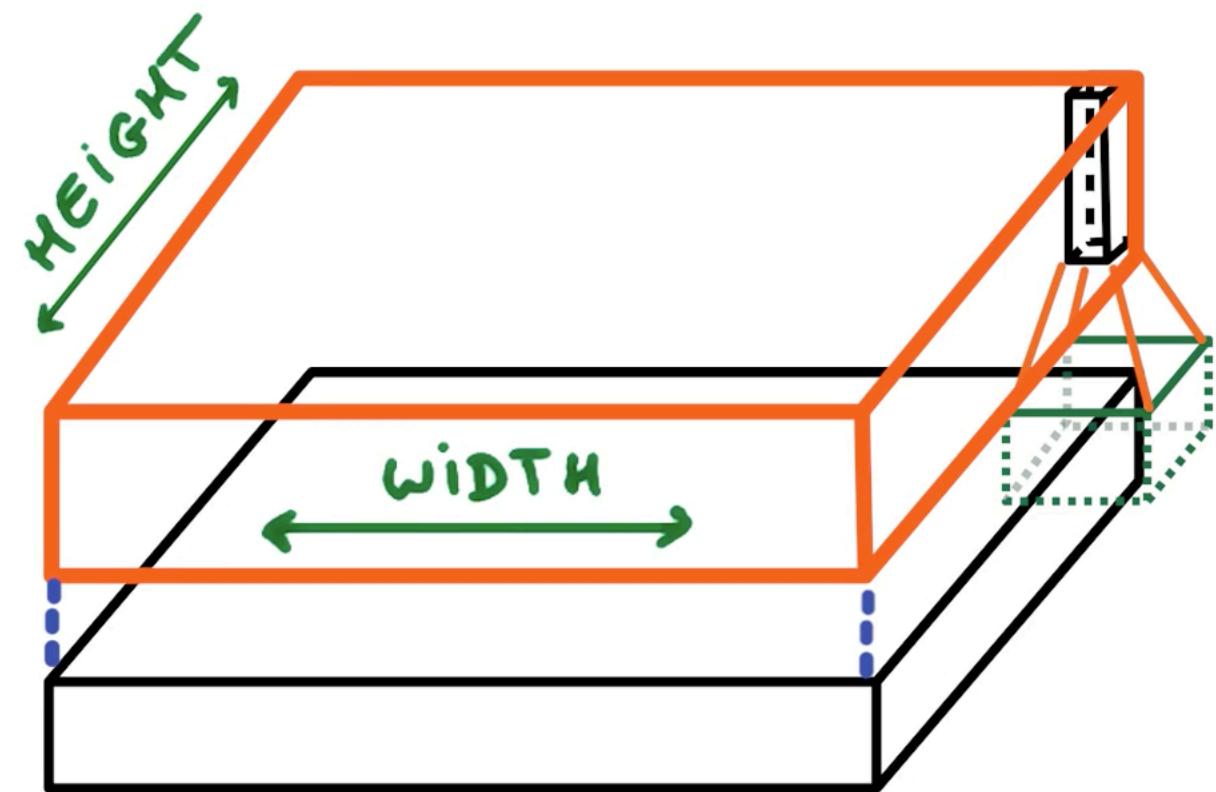
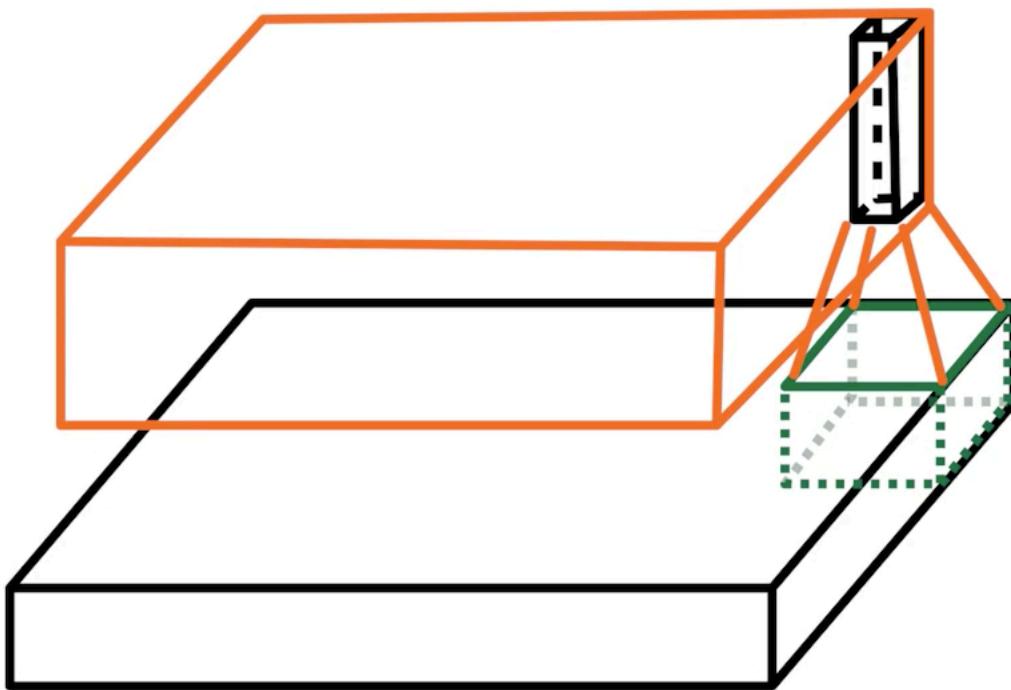


# CONVOLUTIONAL LINGO

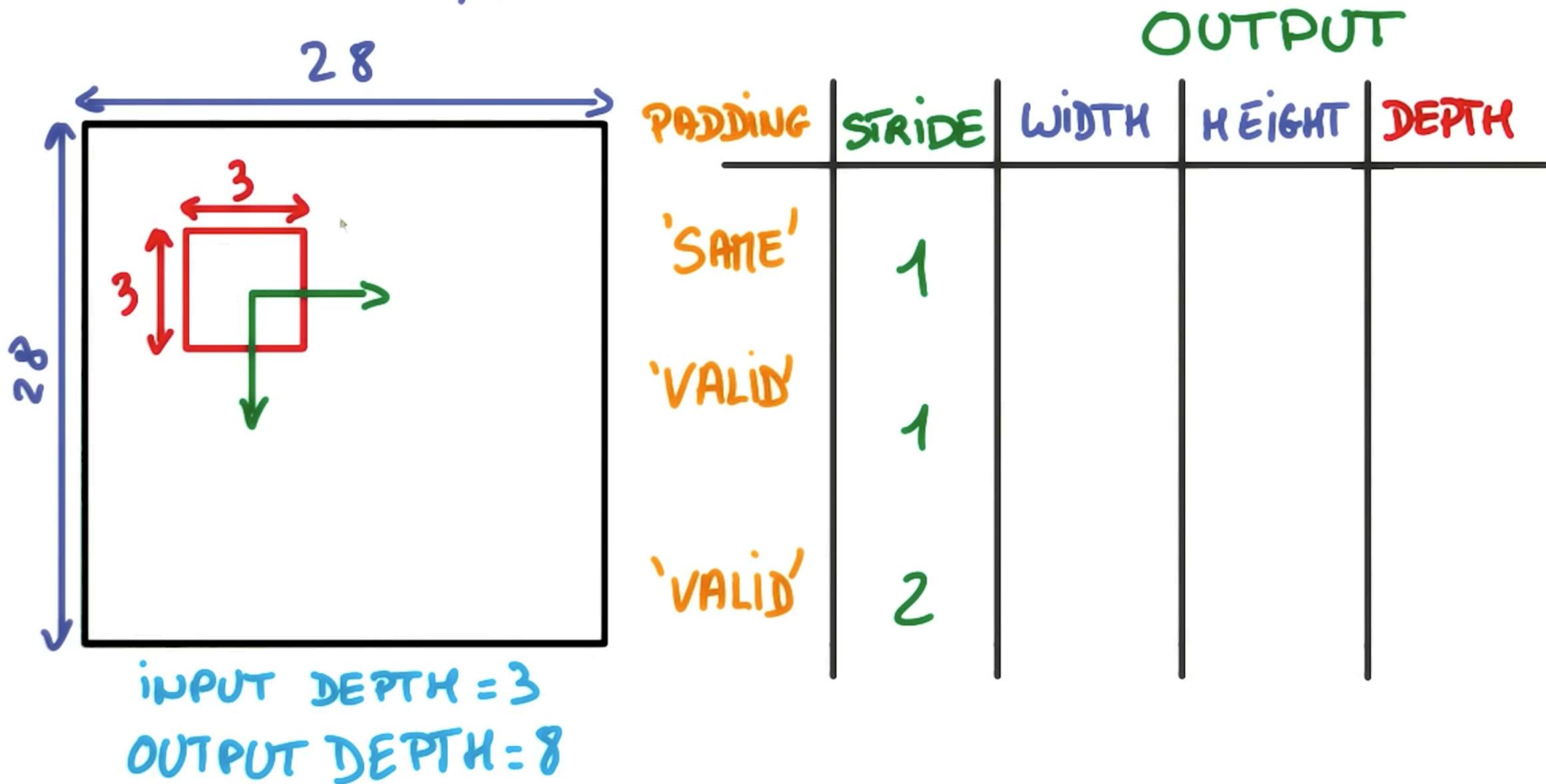


# CONVOLUTIONAL LINGO

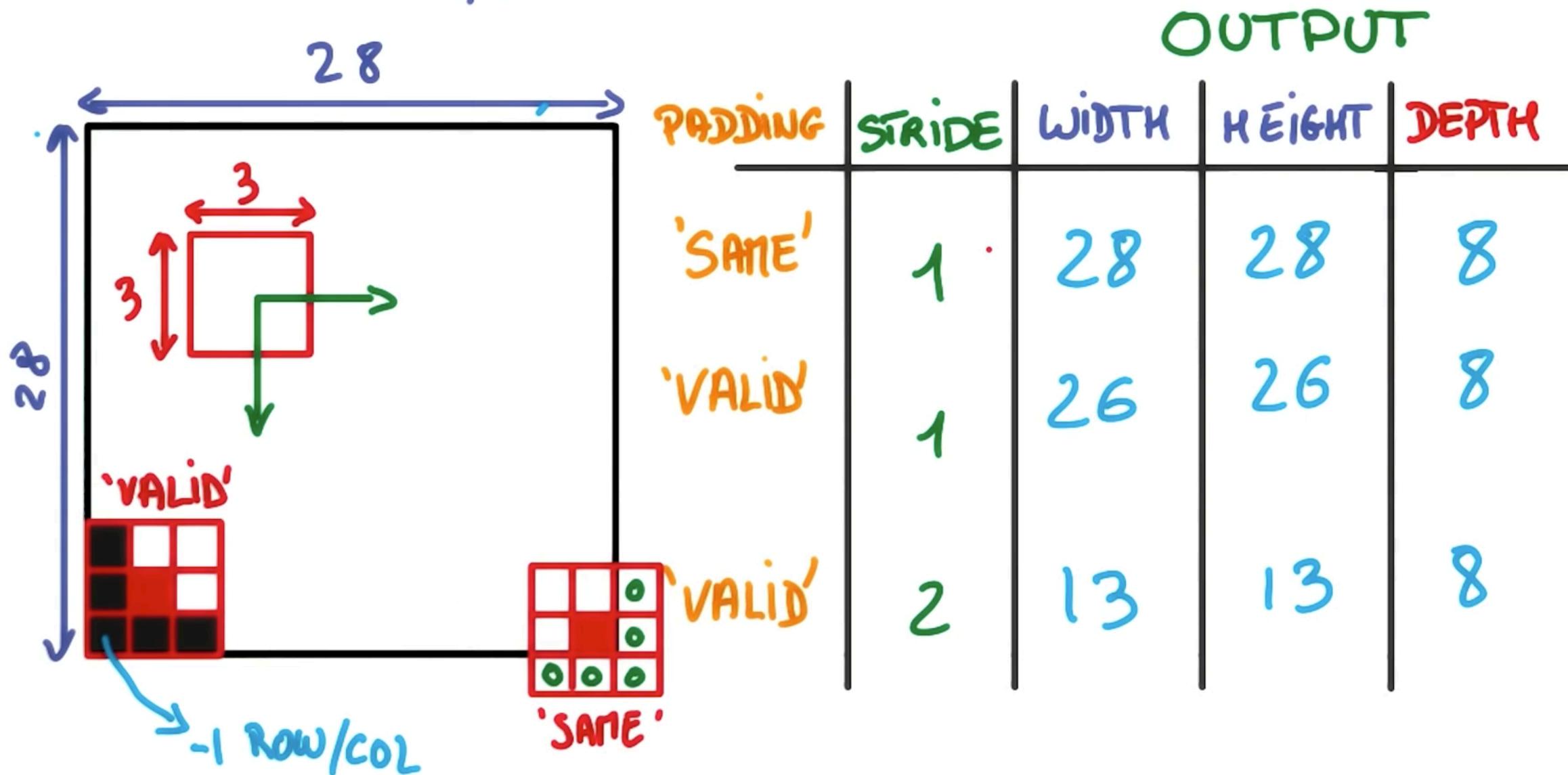
'VALID' PADDING  
'SAME' PADDING



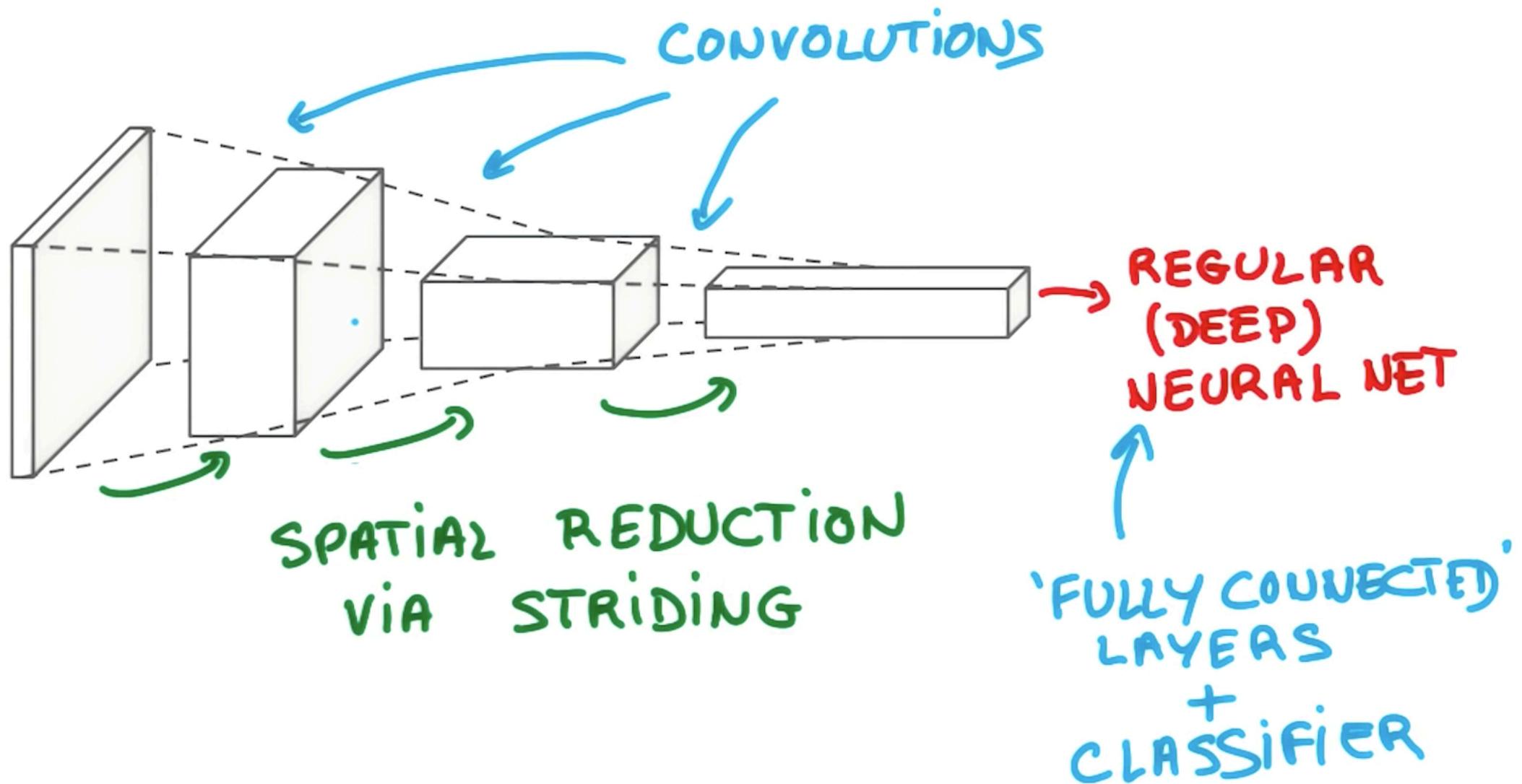
# STRIDES, DEPTH & PADDING



# STRIDES, DEPTH & PADDING



# CONVOLUTIONAL NETWORK



# CHAIN RULE WITH SHARING

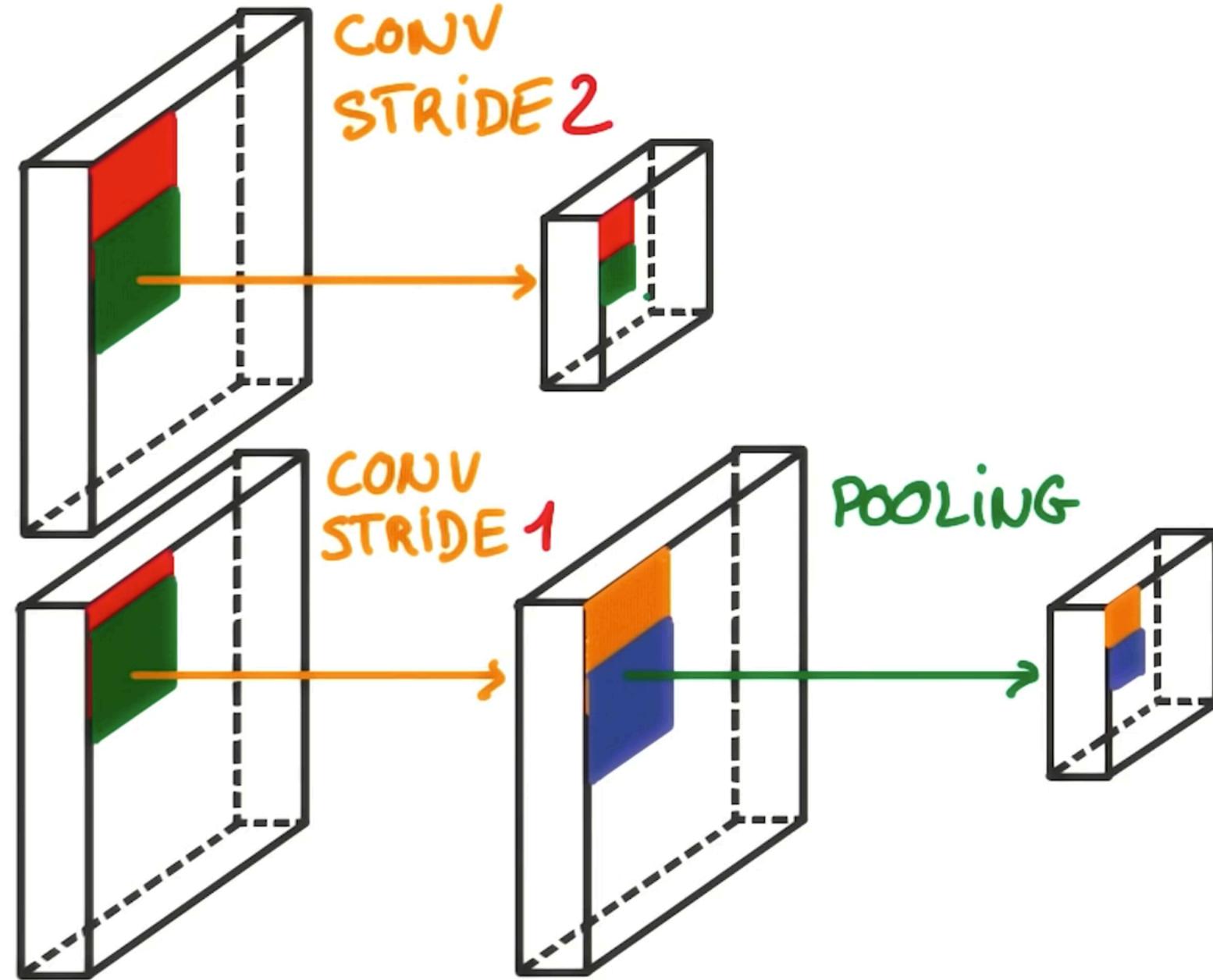
$$\frac{\Delta \mathcal{L}}{\Delta \omega} = \frac{\Delta \mathcal{L}}{\Delta \omega}(x_1) + \frac{\Delta \mathcal{L}}{\Delta \omega}(x_2)$$

ADD UP THE  
GRADIENTS  
FOR EVERY  
PATCH

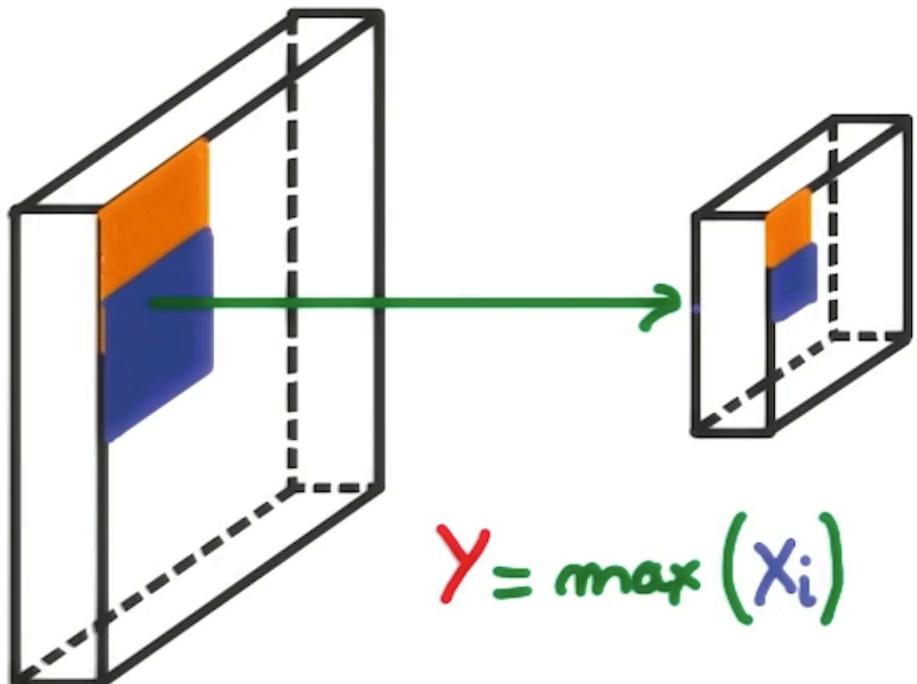
# ADVANCED CONVNET- OLOGY

- POOLING
- 1x1 CONVOLUTIONS
- INCEPTION

# POOLING



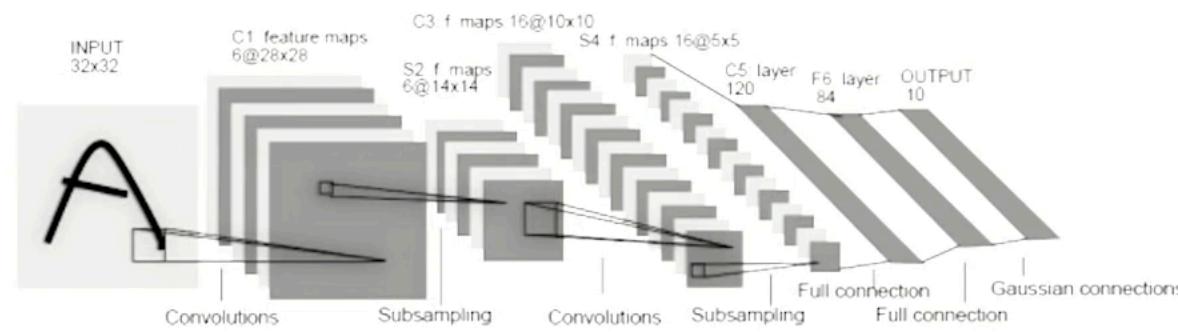
# MAX POOLING



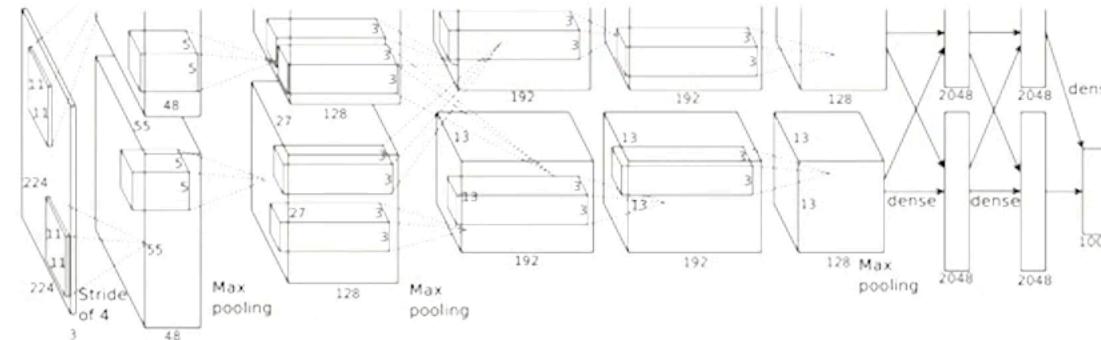
PARAMETER - FREE!  
OFTEN MORE ACCURATE  
MORE EXPENSIVE  
MORE HYPER PARAMETERS  
• POOLING SIZE  
• POOLING STRIDE

CLASSIFIER  
FULLY CONNECTED  
FULLY CONNECTED  
MAX POOLING  
CONVOLUTION  
MAX POOLING  
CONVOLUTION  
IMAGE

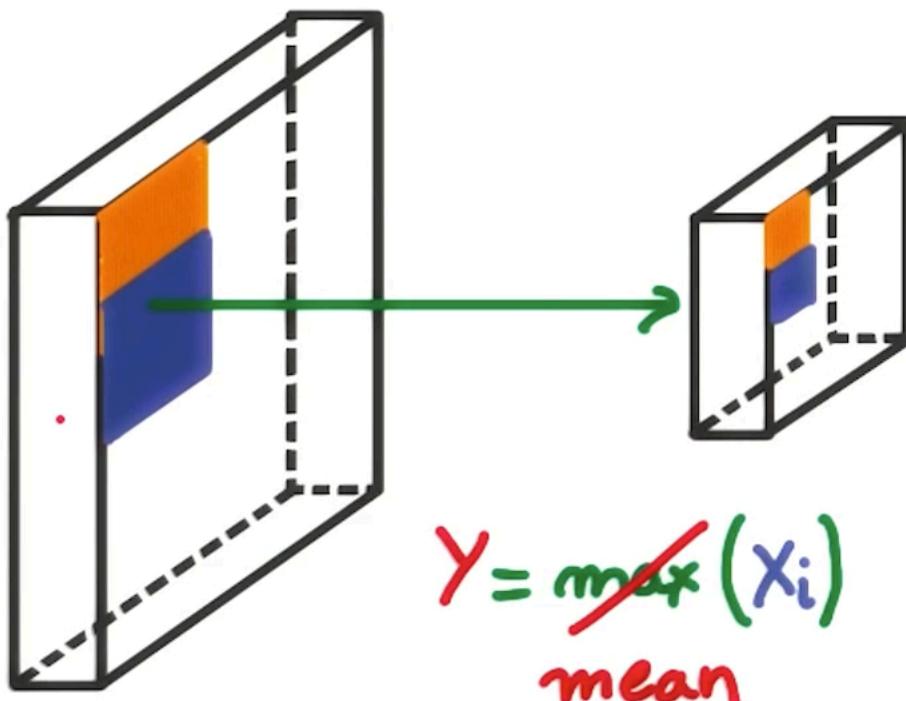
'LENET-5' YANN LECUN '98



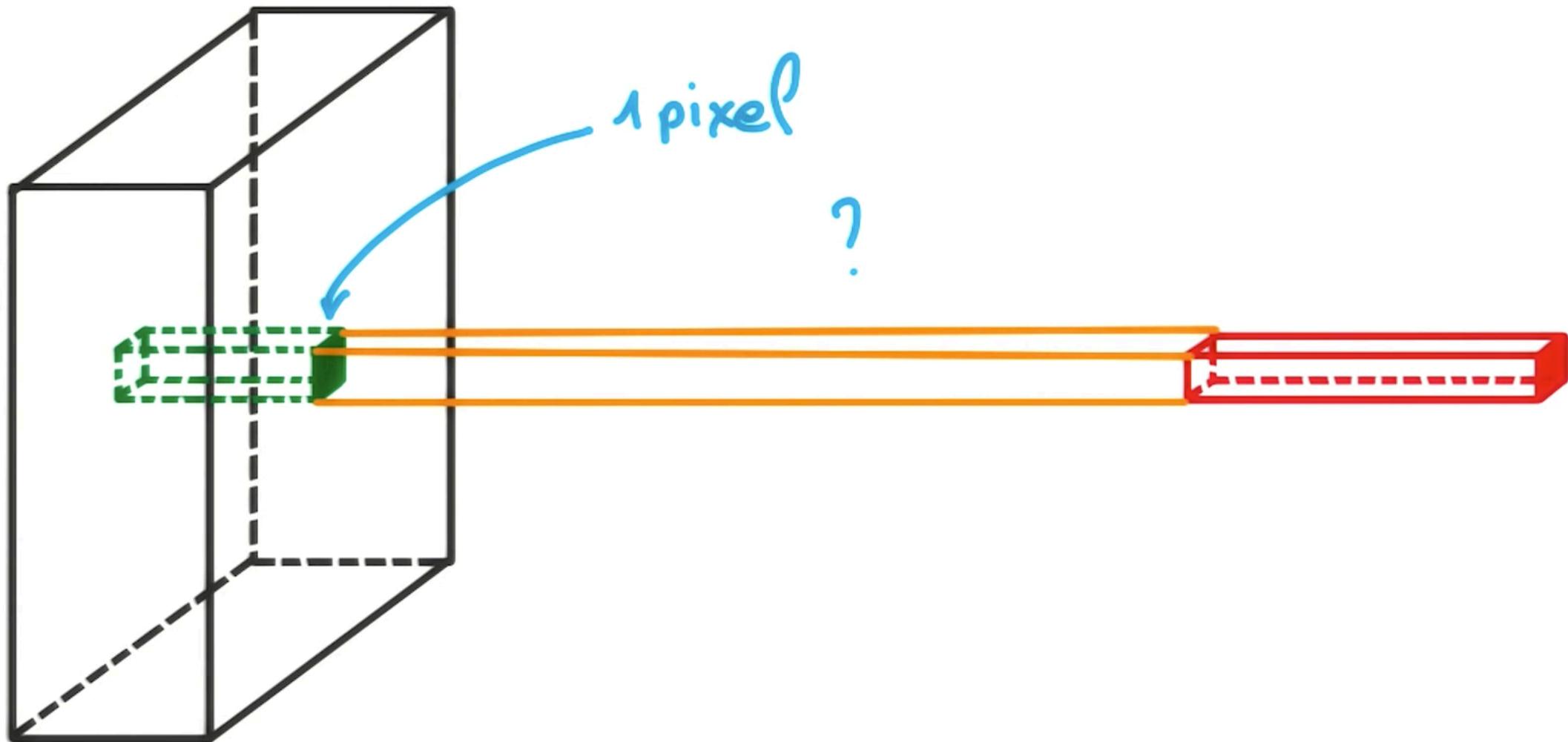
'ALEXNET' ALEX KRIZHEVSKY '12



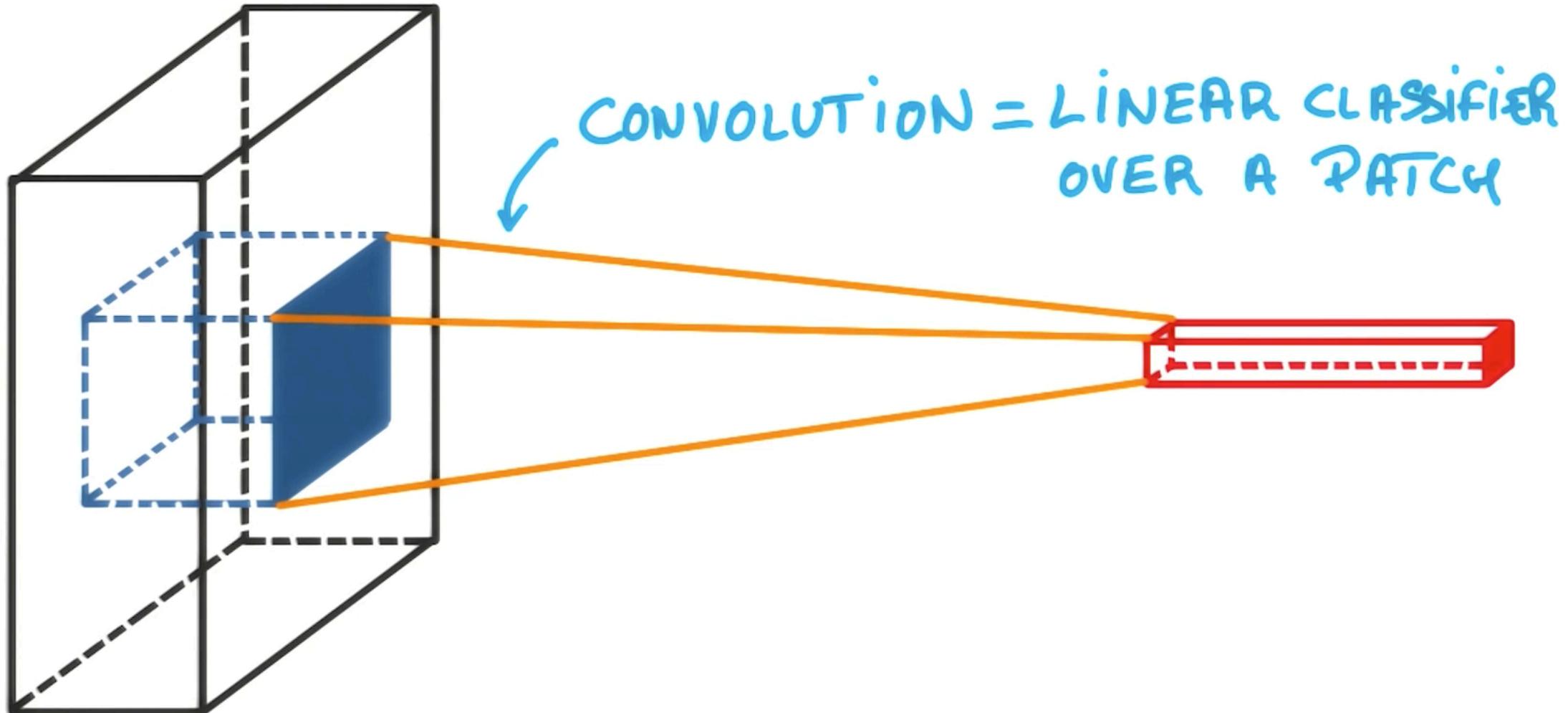
# AVERAGE ~~MAX~~ POOLING



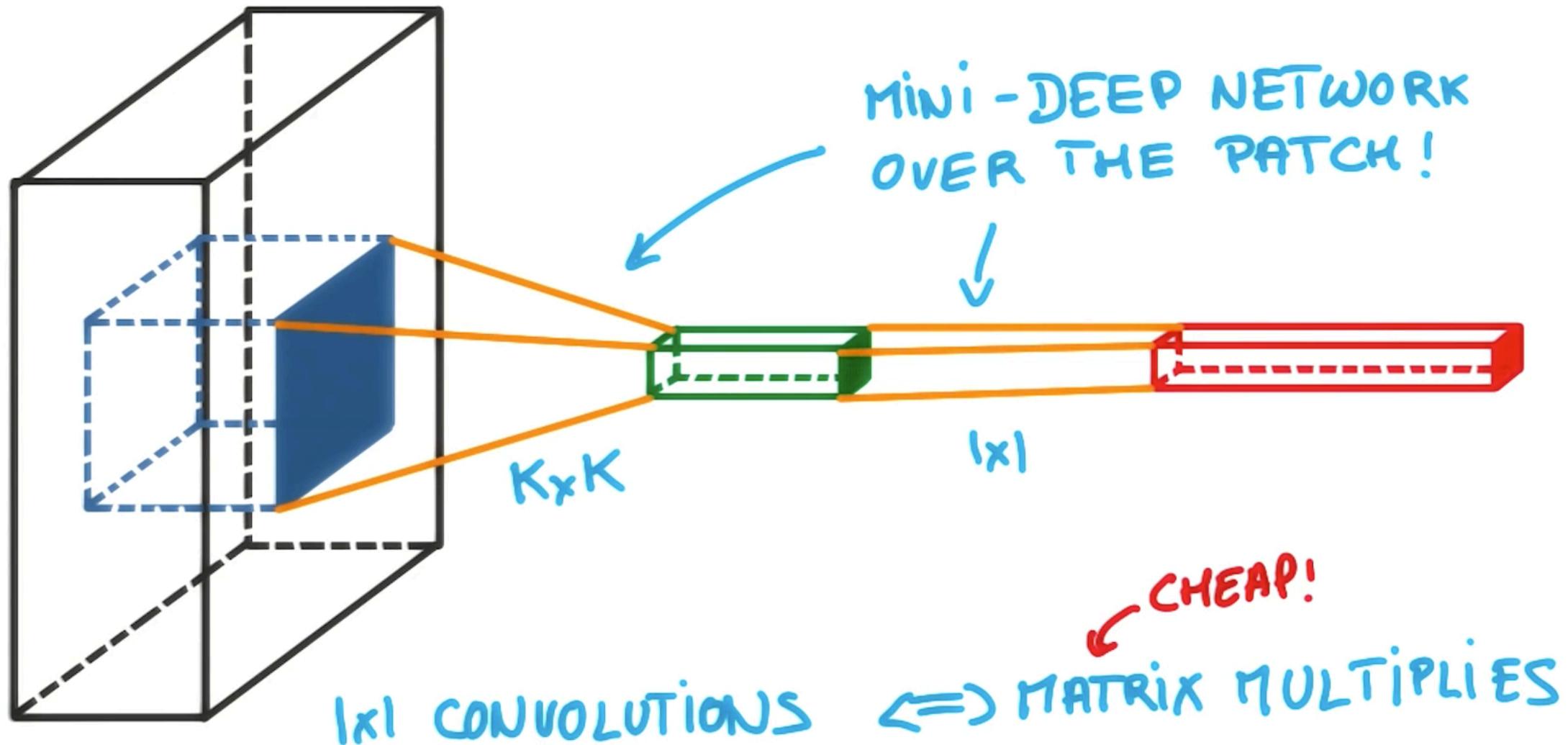
# $1 \times 1$ CONVOLUTIONS



## $1 \times 1$ CONVOLUTIONS



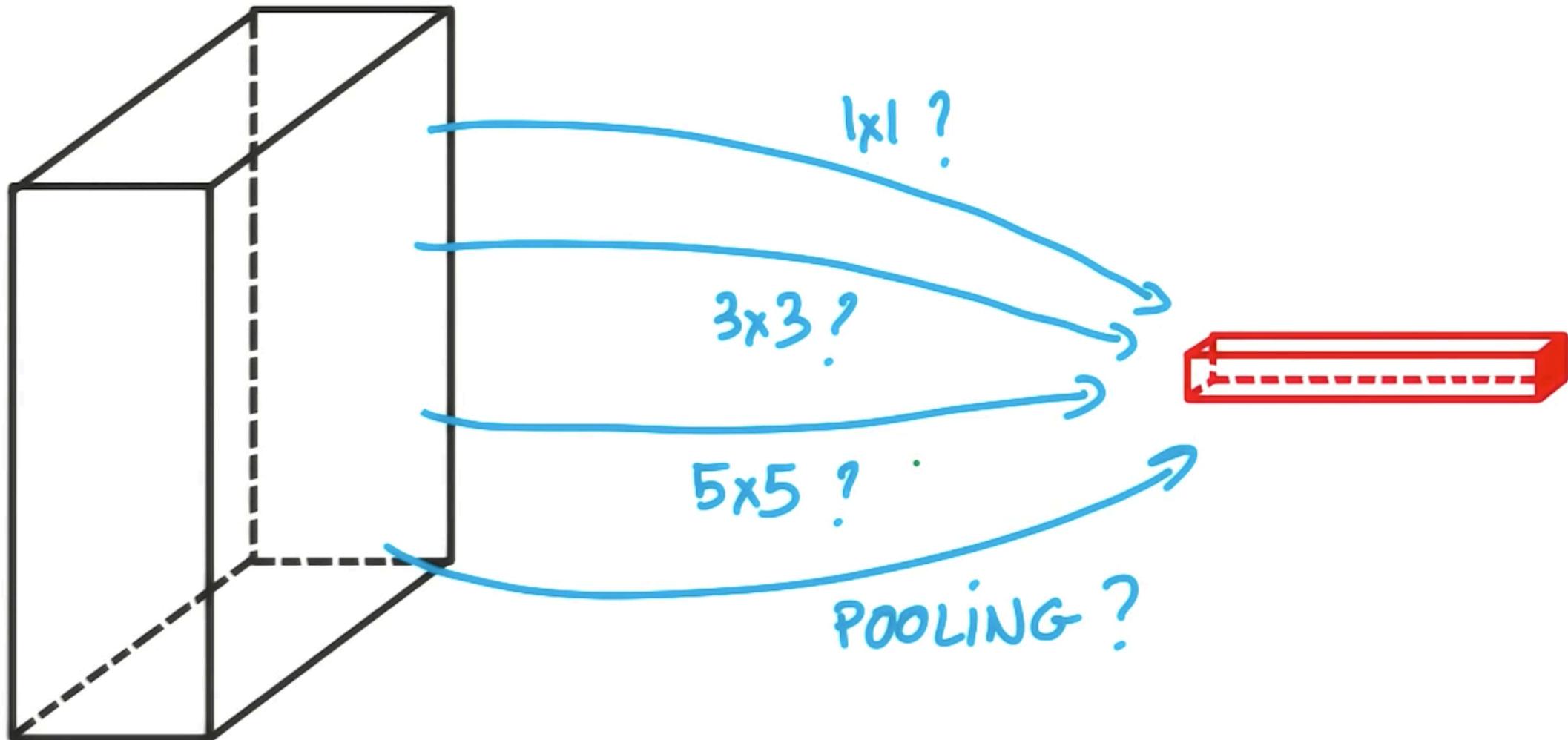
## $1 \times 1$ CONVOLUTIONS



AVERAGE POOLING

$1 \times 1$  CONVOLUTIONS .

# INCEPTION MODULES



# INCEPTION MODULES

