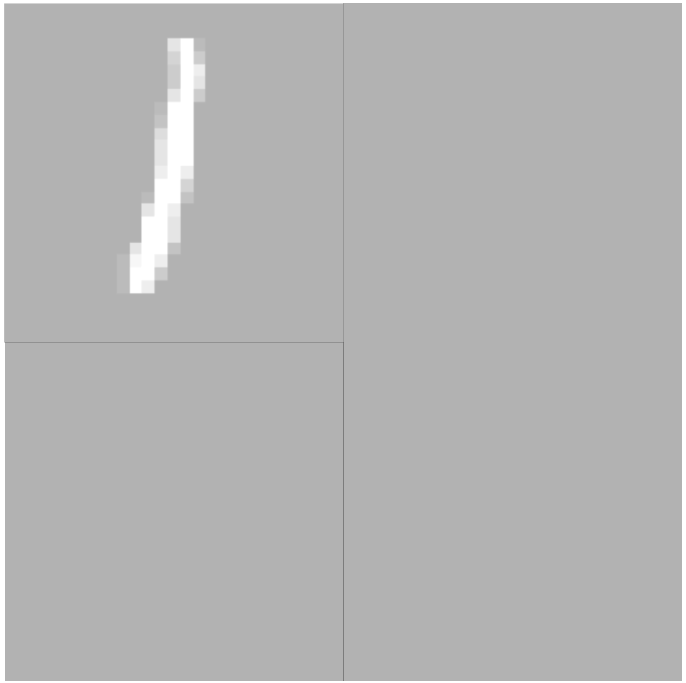
Spatial Convolution

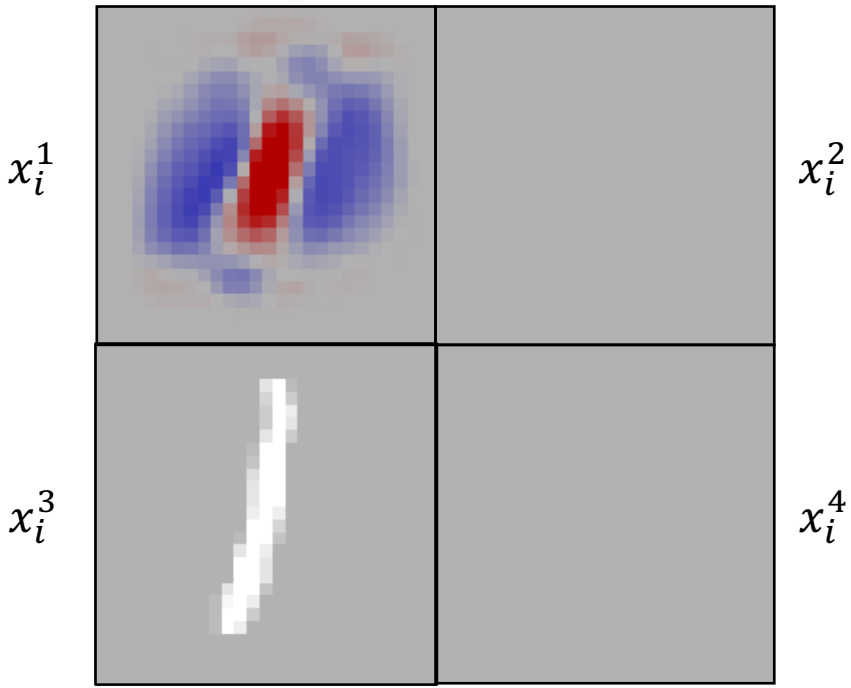
Matthew Engelhard

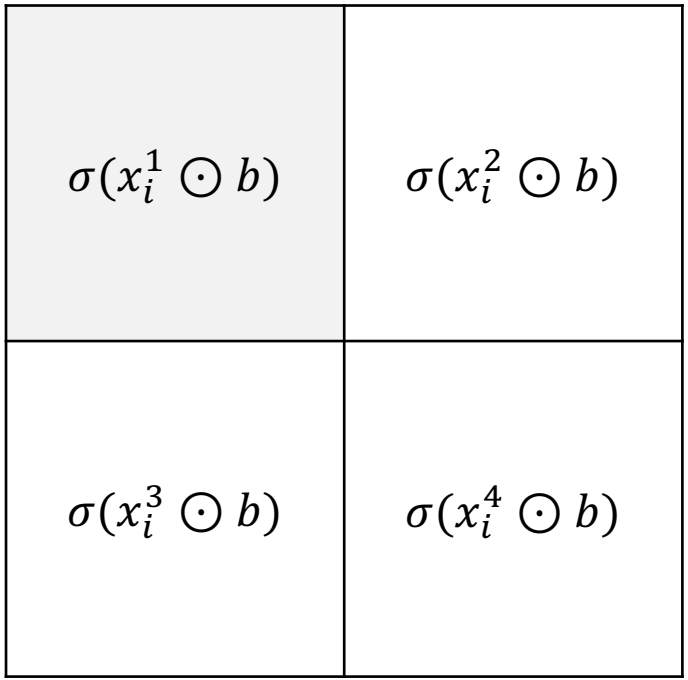
Many slides created by Tim Dunn

What if we'd like to find a 1 anywhere in a larger image?

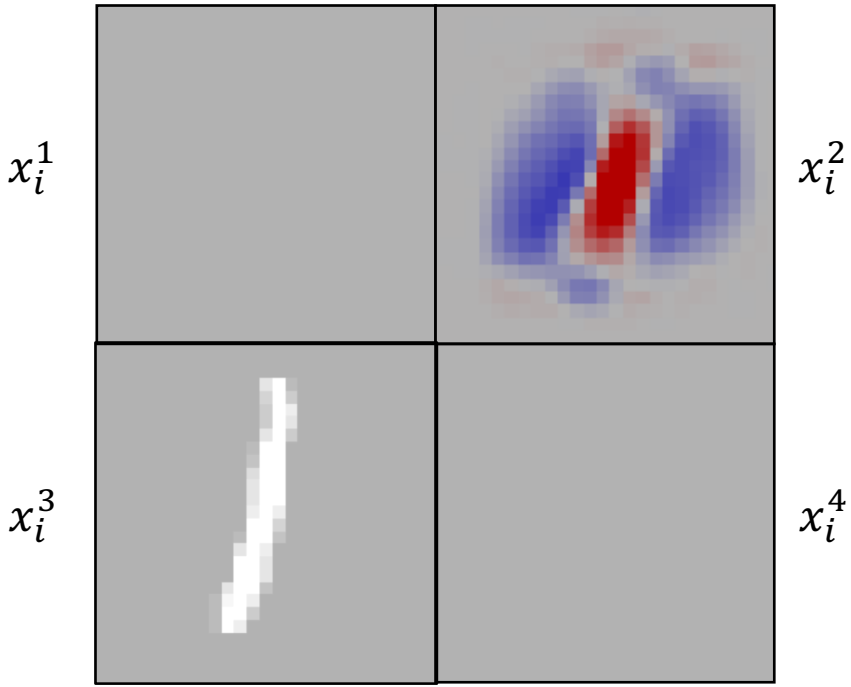


Examining filter output $\sigma(x_i^R \odot b)$, where x_i^R is the portion of image i where the filter is placed.

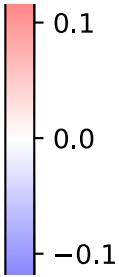




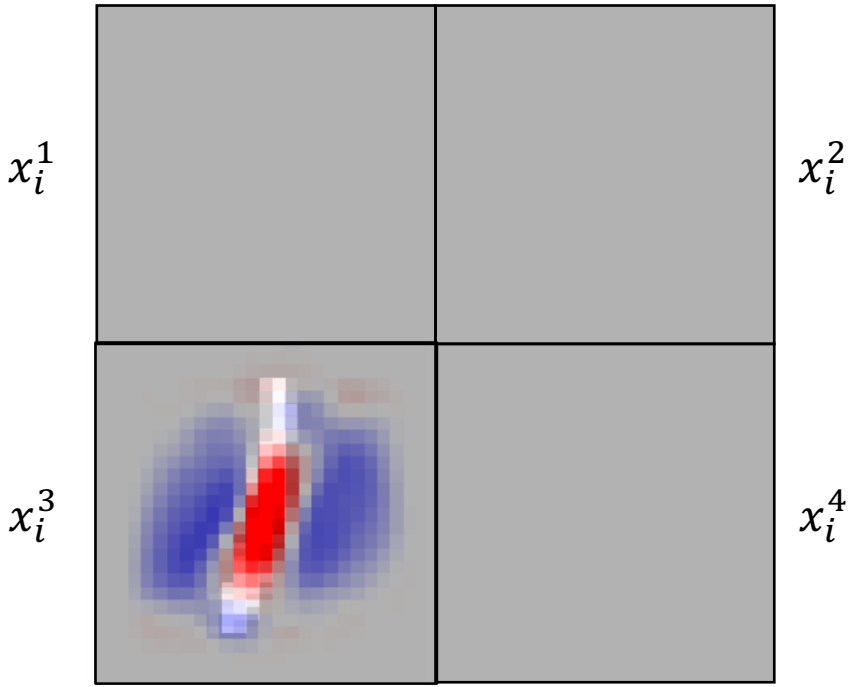
Examining filter output $\sigma(x_i^R \odot b)$, where x_i^R is the portion of image i where the filter is placed.

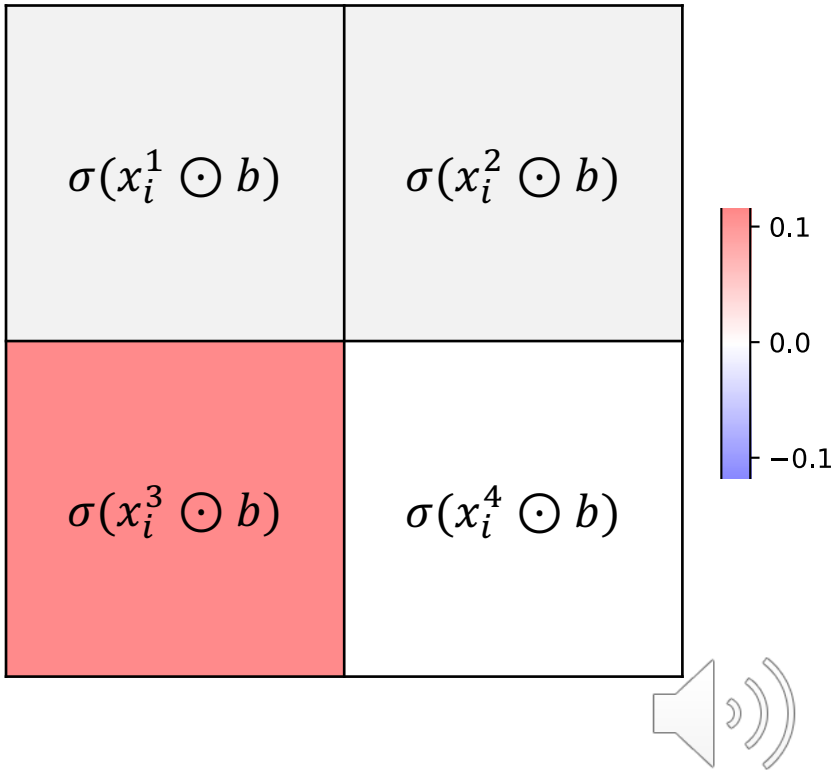


$\sigma(x_i^1 \odot b)$	$\sigma(x_i^2 \odot b)$
$\sigma(x_i^3 \odot b)$	$\sigma(x_i^4 \odot b)$

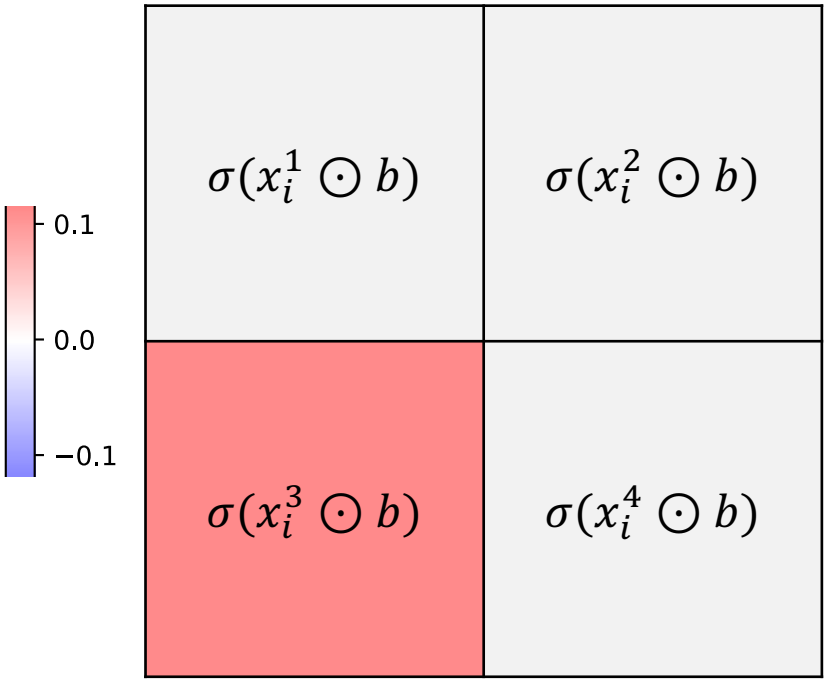


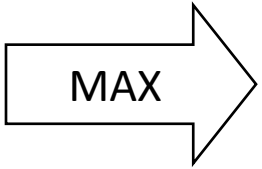
Examining filter output $\sigma(x_i^R \odot b)$, where x_i^R is the portion of image i where the filter is placed.

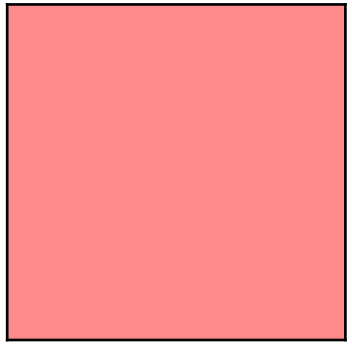




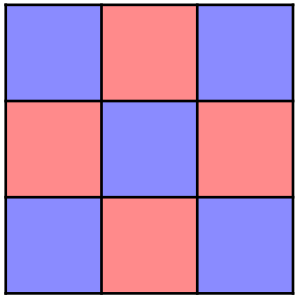
What if we want to know if a 1 is present *anywhere* in the image?



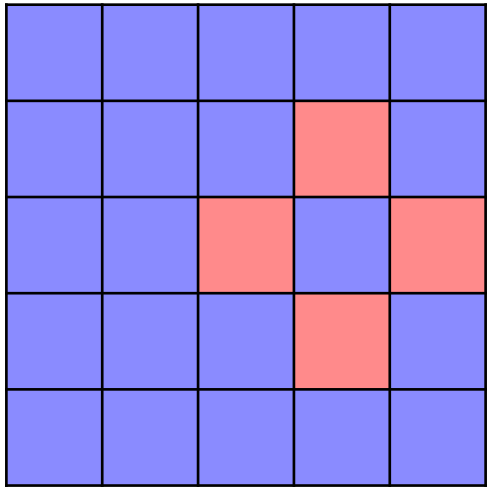




An Example…



filter



image

An Example…

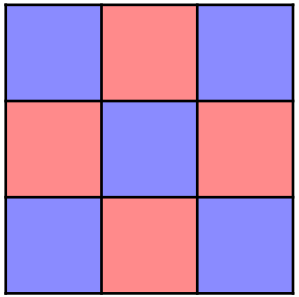
-1	1	-1
1	-1	1
-1	1	-1

filter

-1	-1	-1	-1	-1
-1	-1	-1	1	-1
-1	-1	1	-1	1
-1	-1	-1	1	-1
-1	-1	-1	-1	-1

image

An Example…



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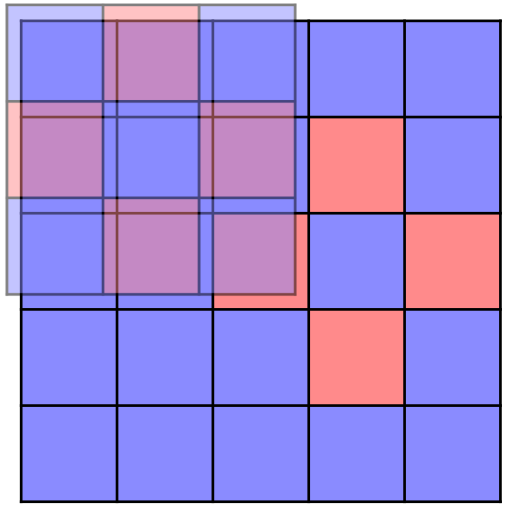

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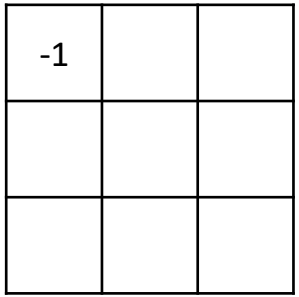
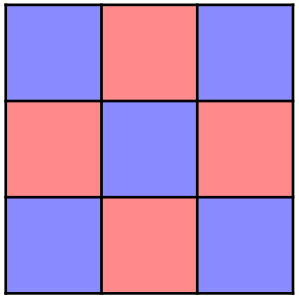
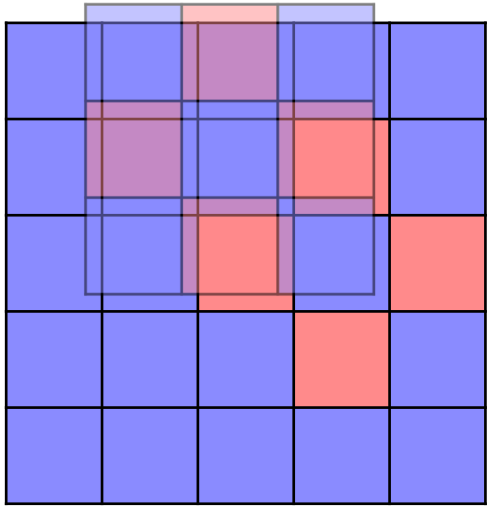


$x_i^R \odot b$

An Example…





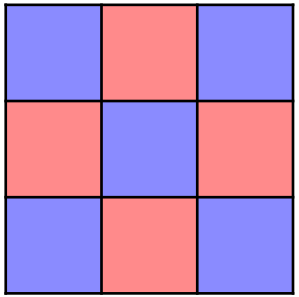
-1	5	

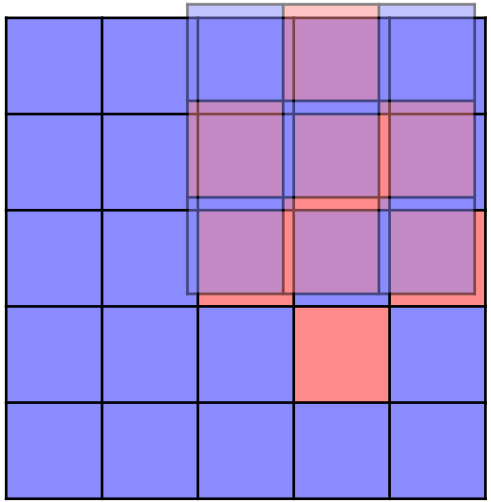
filter

image

$x_i^R \odot b$

An Example…





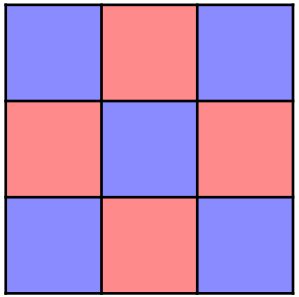
-1	5	-5

filter

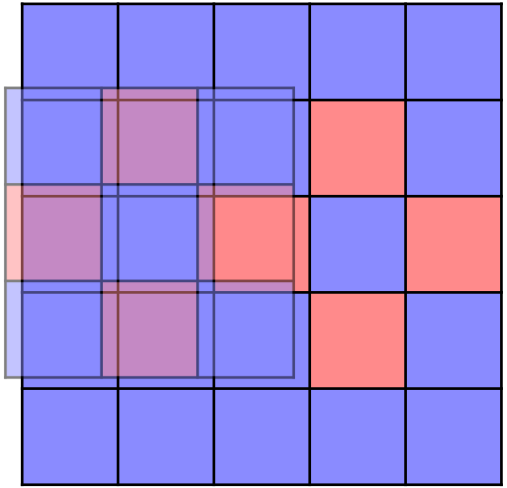
image

$x_i^R \odot b$

An Example…



filter

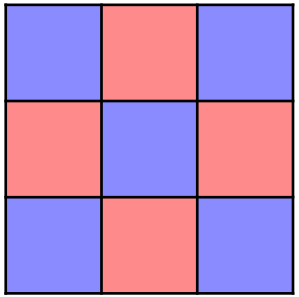


image

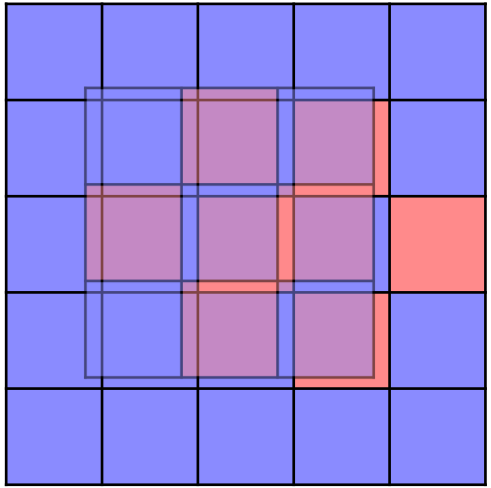
-1	5	-5
3		

$x_i^R \odot b$

An Example…



filter

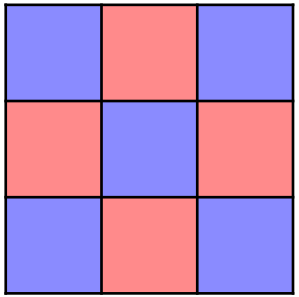


image

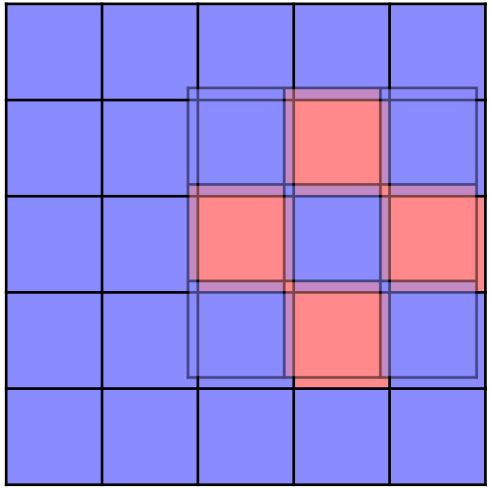
-1	5	-5
3	-5	

$x_i^R \odot b$

An Example…



filter

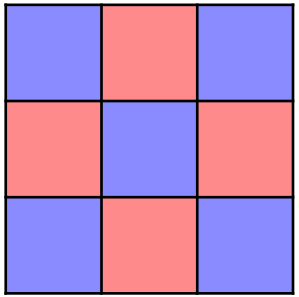


image

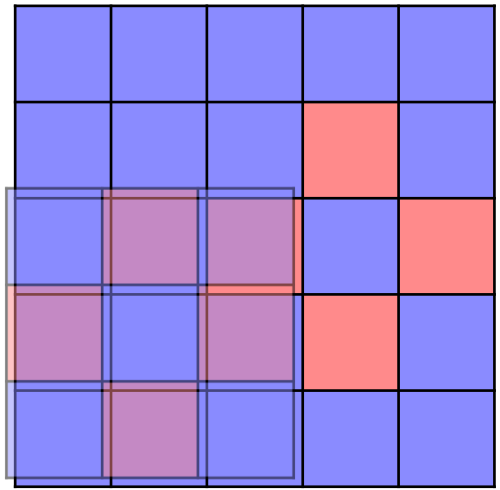
-1	5	-5
3	-5	9

$x_i^R \odot b$

An Example…



filter

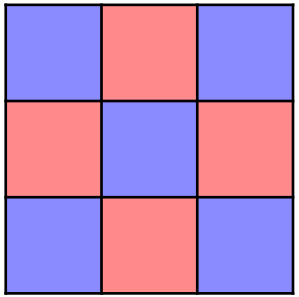


image

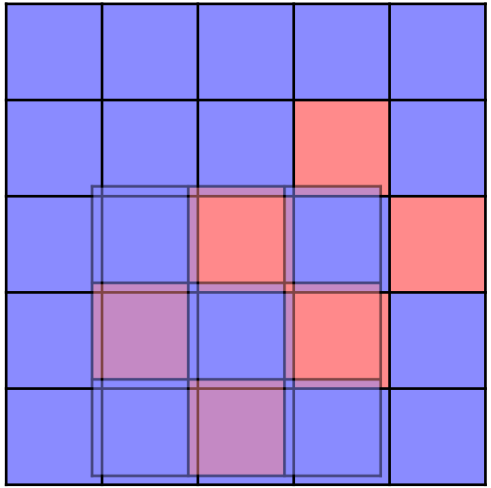
-1	5	-5
3	-5	9
-1		

$x_i^R \odot b$

An Example…



filter

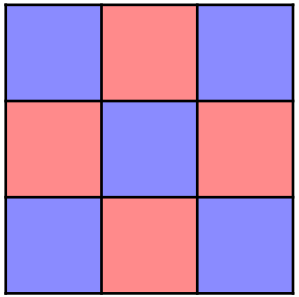


image

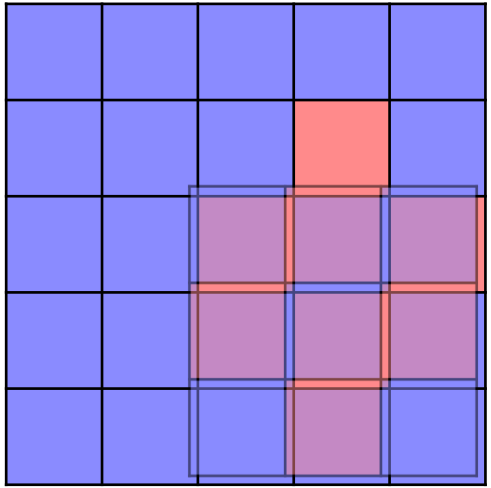
-1	5	-5
3	-5	9
-1	5	

$x_i^R \odot b$

An Example…



filter

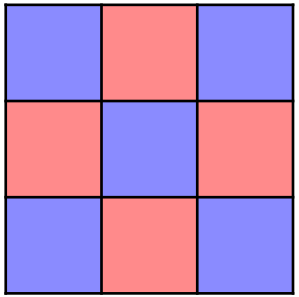


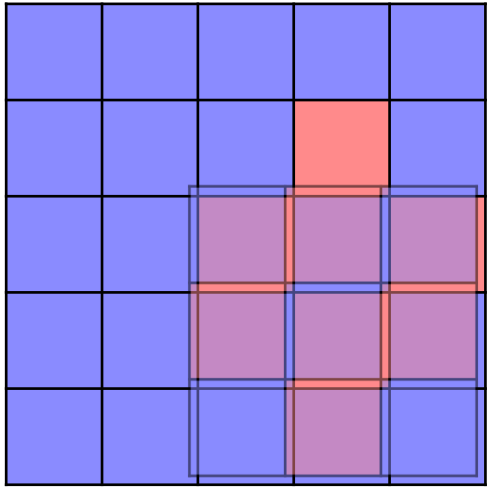
image

-1	5	-5
3	-5	9
-1	5	-5

$x_i^R \odot b$

An Example…





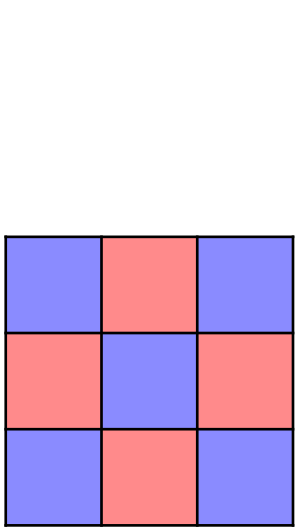
-1	5	-5
3	-5	9
-1	5	-5

filter

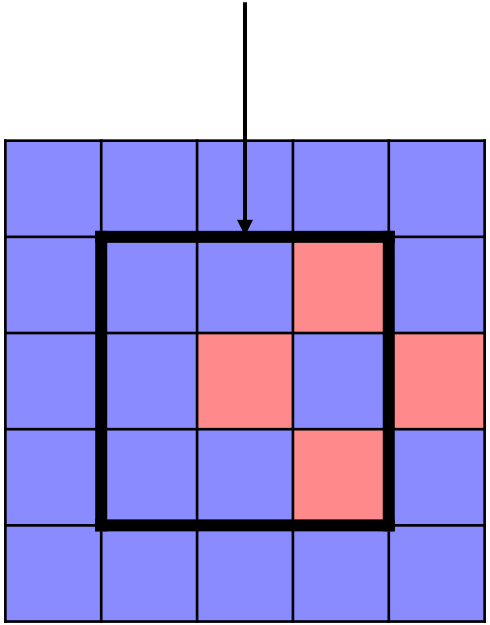
image

$x_i^R \odot b$

Each location where the filter was centered has been evaluated: “how similar is this location to the filter”?



filter

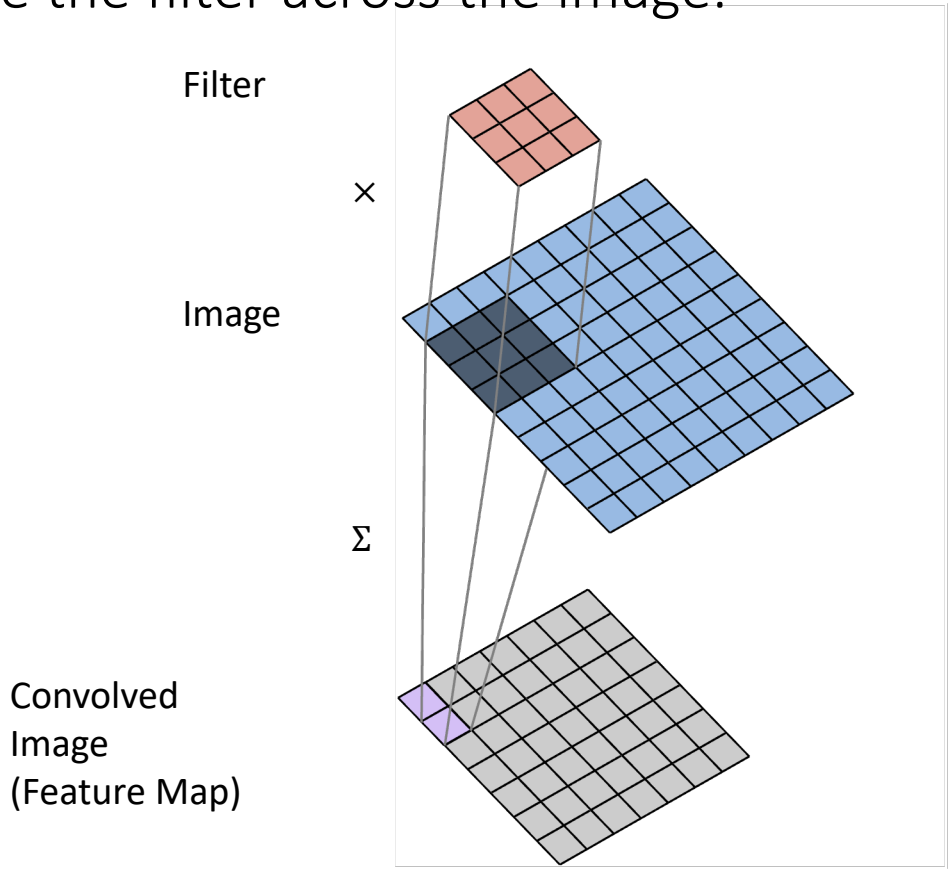


image

-1	5	-5
3	-5	9
-1	5	-5

$x_i^R \odot b$

We perform “2D Spatial Convolution” as we move the filter across the image.



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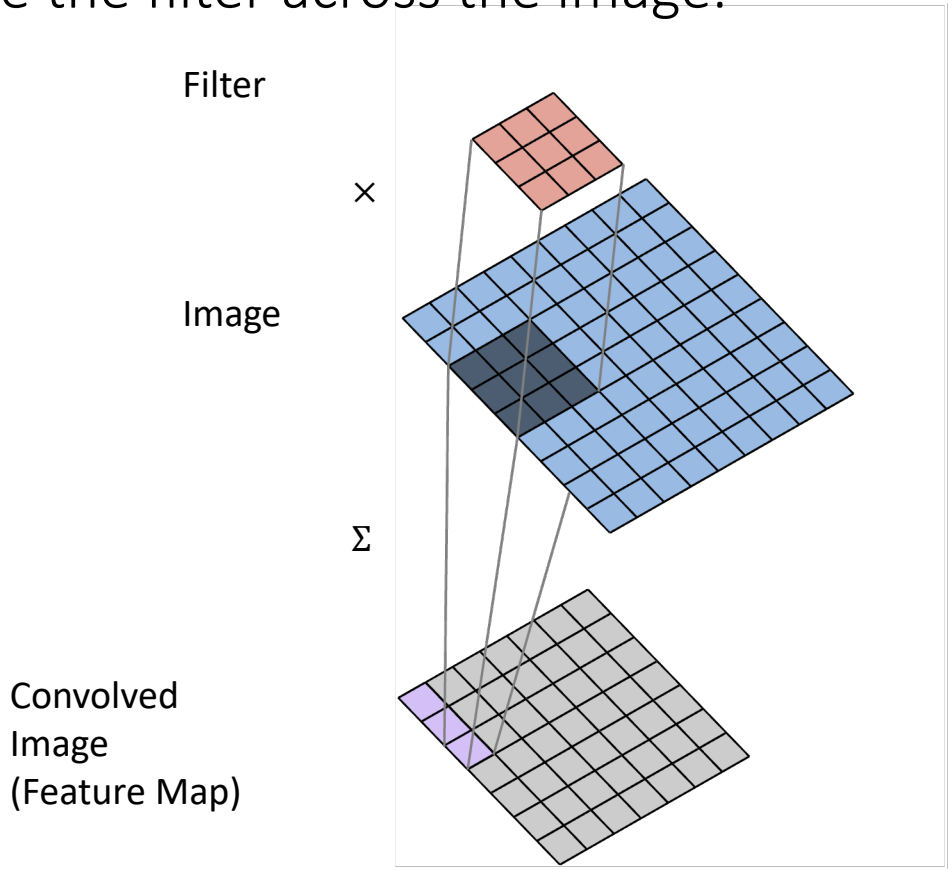
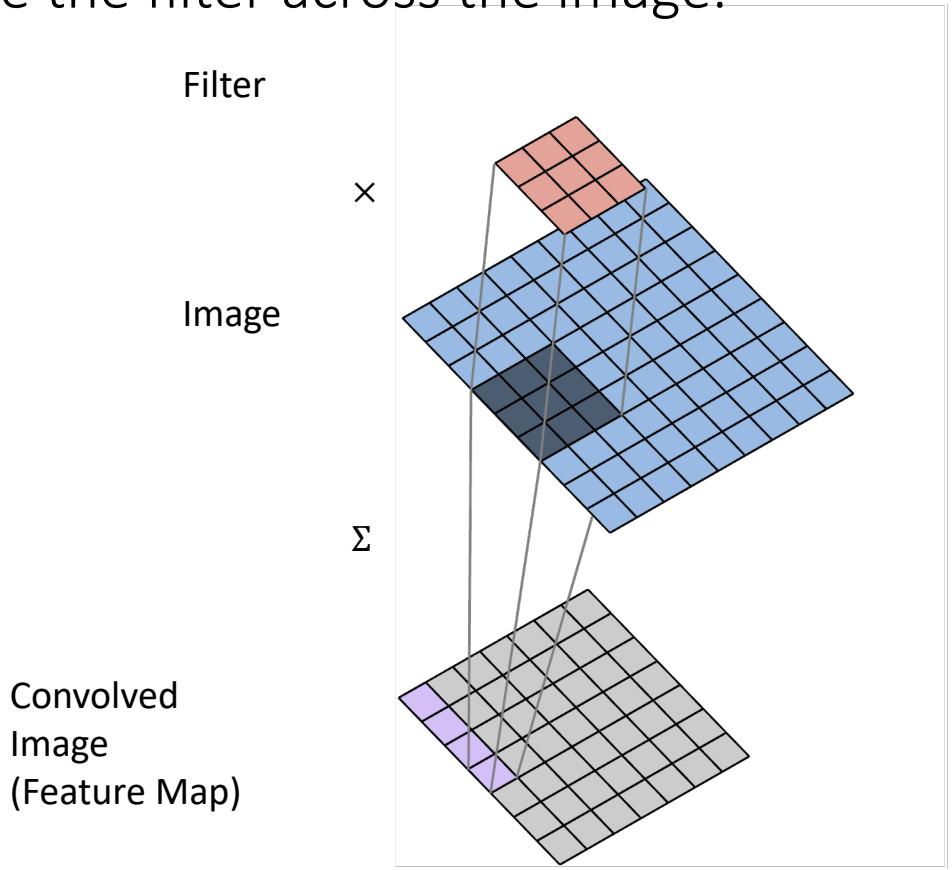
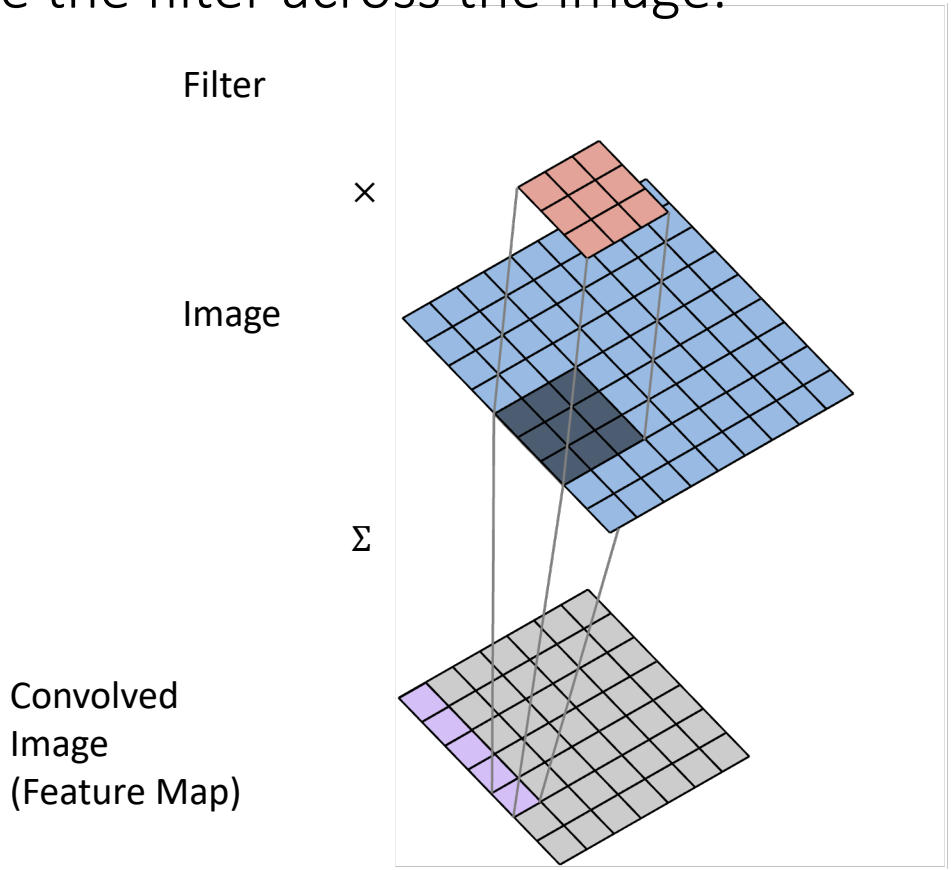
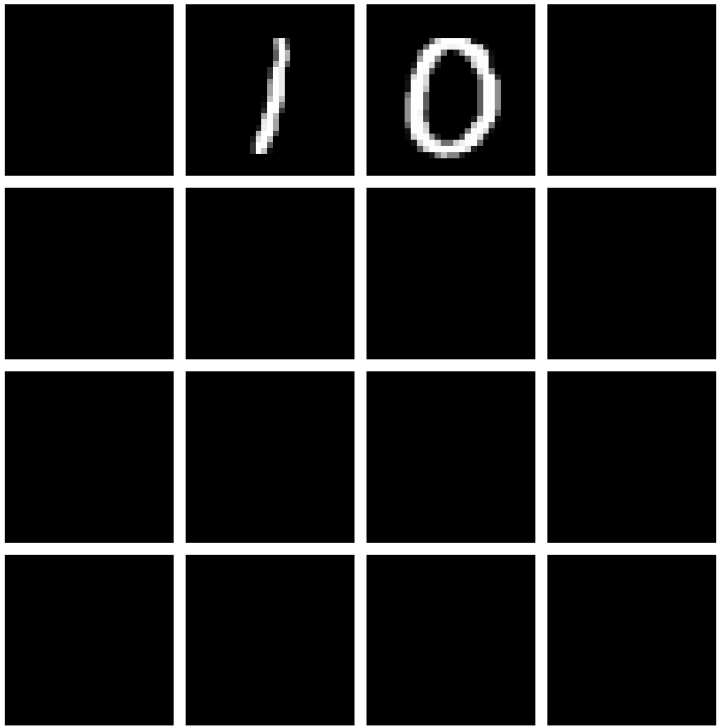


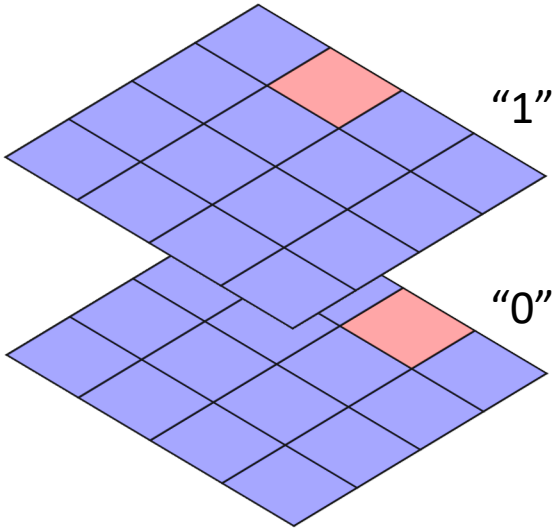
We perform “2D Spatial Convolution” as we move the filter across the image.



We perform “2D Spatial Convolution”
as we move the filter across the image.



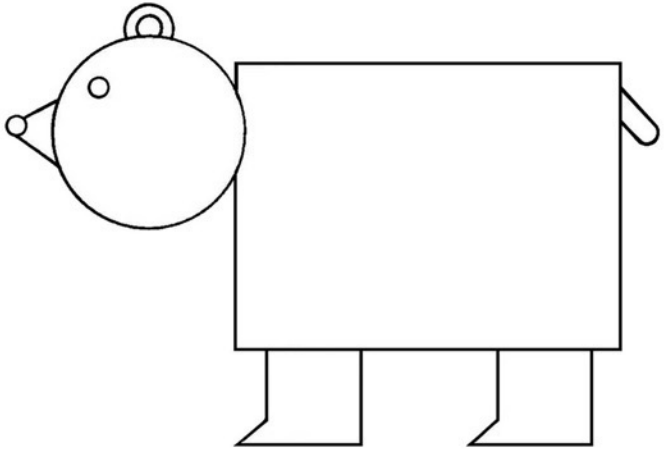


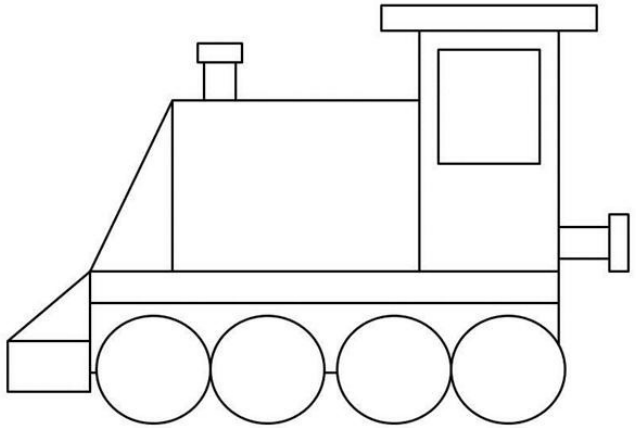


In this way, we learn to identify a hierarchy of features rather than a huge number of complex features

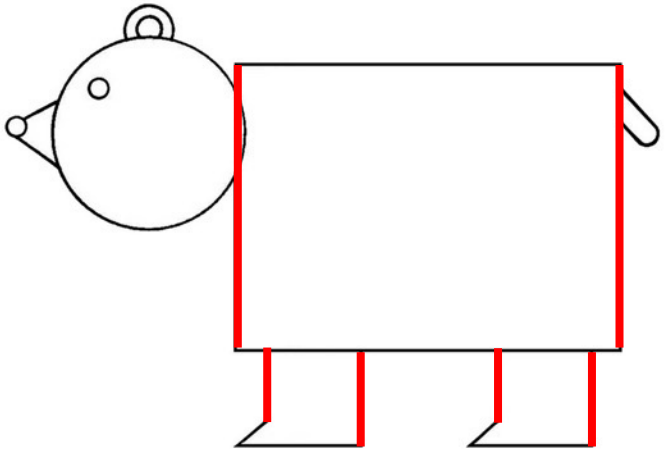
CNNs Take Advantage of Repeated, Hierarchical Structure in Images

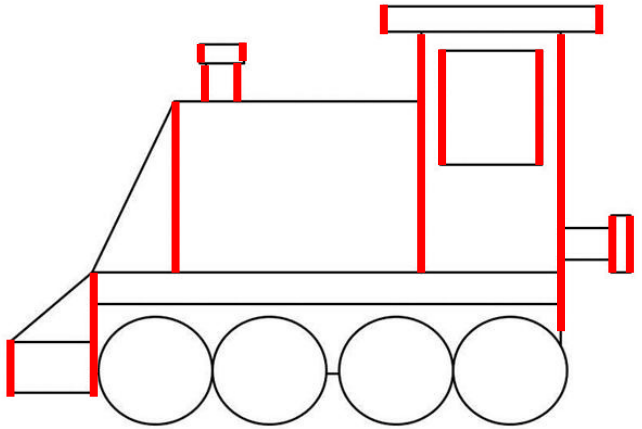
CNNs Take Advantage of Repeated, Hierarchical Structure in Images





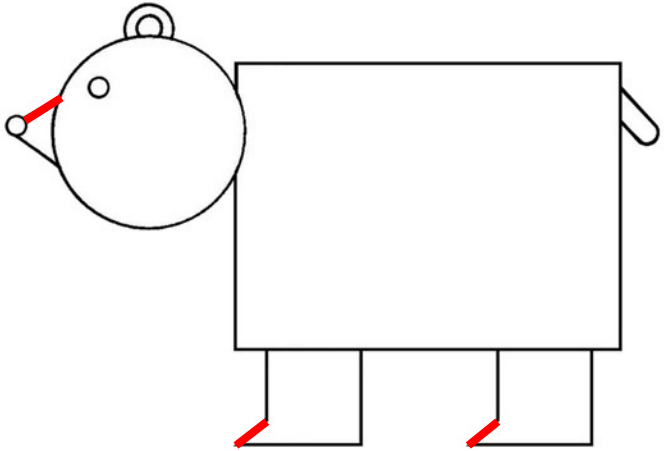
CNNs Take Advantage of Repeated, Hierarchical Structure in Images

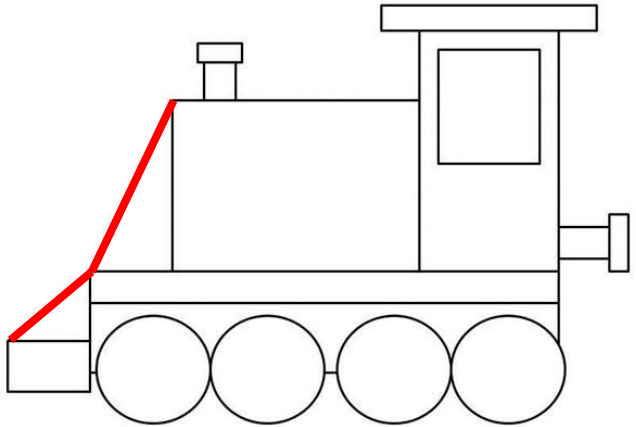




Low-level structure: lines, curves

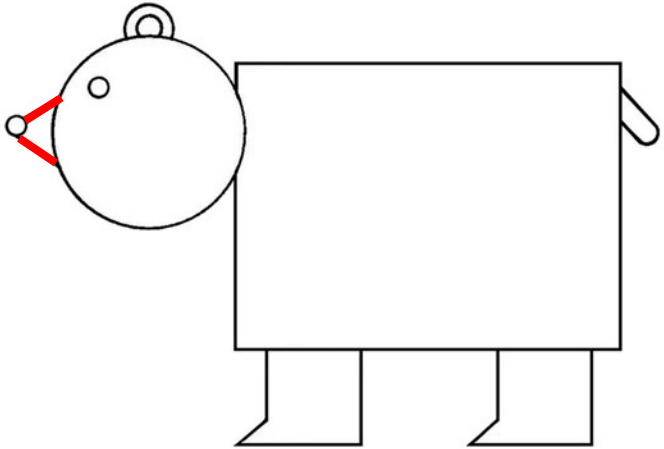
CNNs Take Advantage of Repeated, Hierarchical Structure in Images

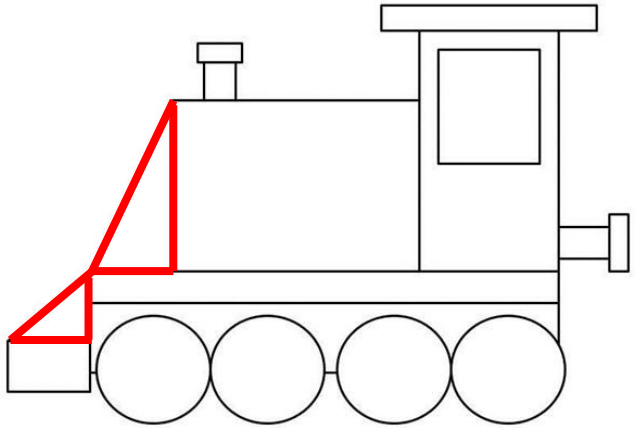




Low-level structure: lines, curves

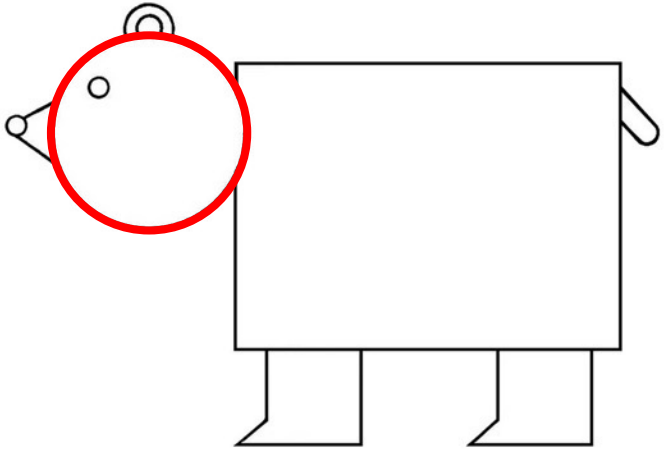
CNNs Take Advantage of Repeated, Hierarchical Structure in Images

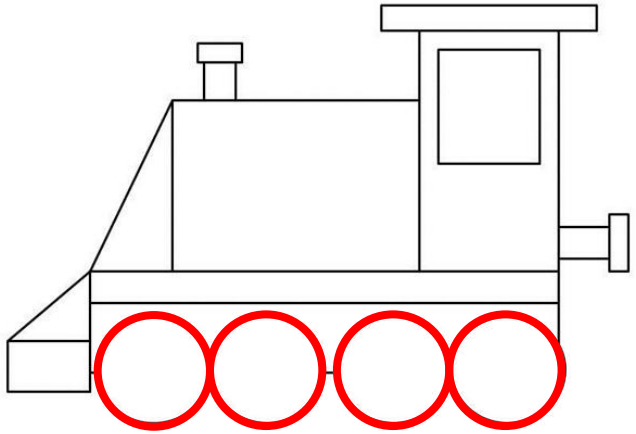




Mid-level structure: shapes

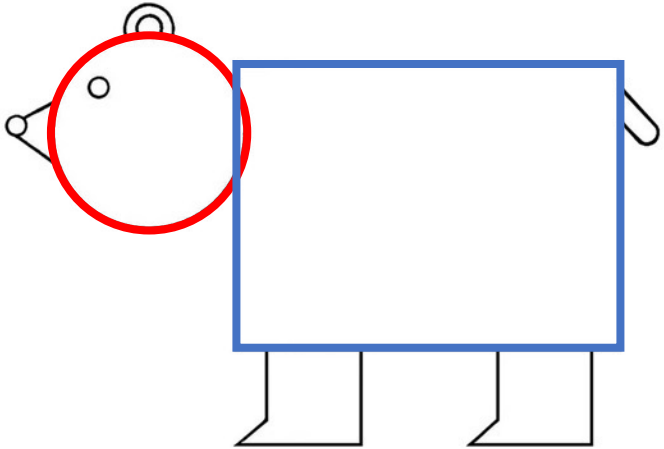
CNNs Take Advantage of Repeated, Hierarchical Structure in Images

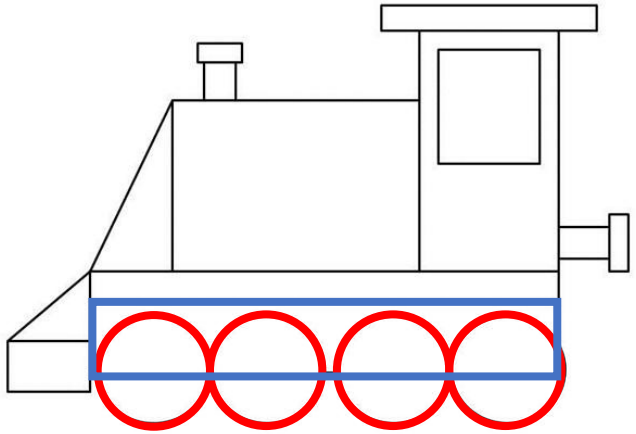




Mid-level structure: shapes

CNNs Take Advantage of Repeated, Hierarchical Structure in Images

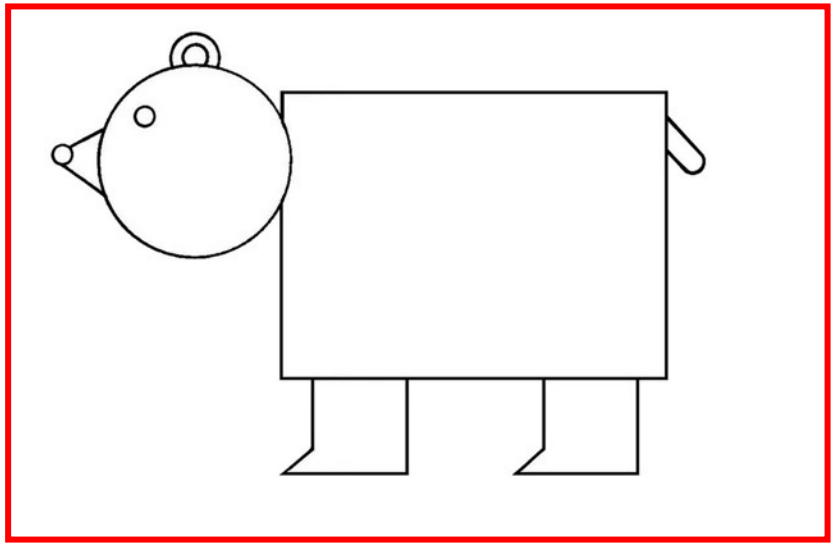




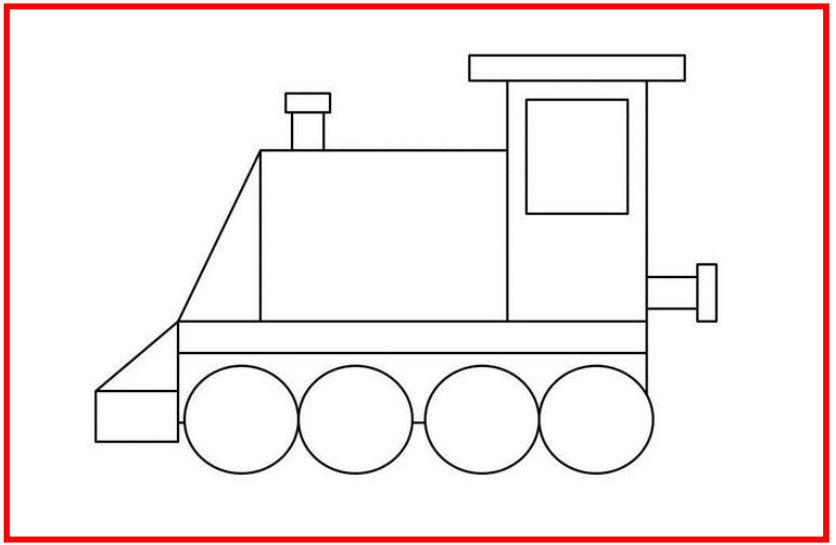
High-level structure: groups of shapes

CNNs Take Advantage of Repeated, Hierarchical Structure in Images

Bear



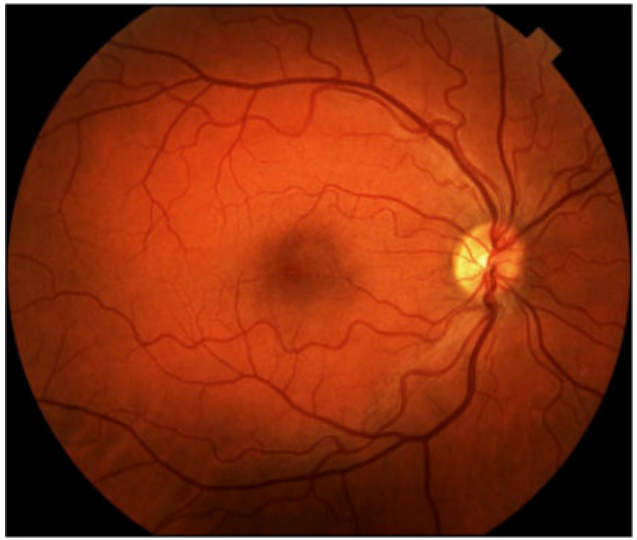
Train



High-level structure: groups of shapes → objects

Deep Learning for Image Analysis

Diabetic Retinopathy
Classification



Healthy Retina

Unhealthy Retina

Summary

- The **convolution** operation is the building block of the convolutional neural network (CNN)
- Convolving an image with a filter gives us a **feature map** that tells us how much each region of the image matches the filters
- CNNs learn to recognize **high-level structure** in images by building **hierarchical representations of features**