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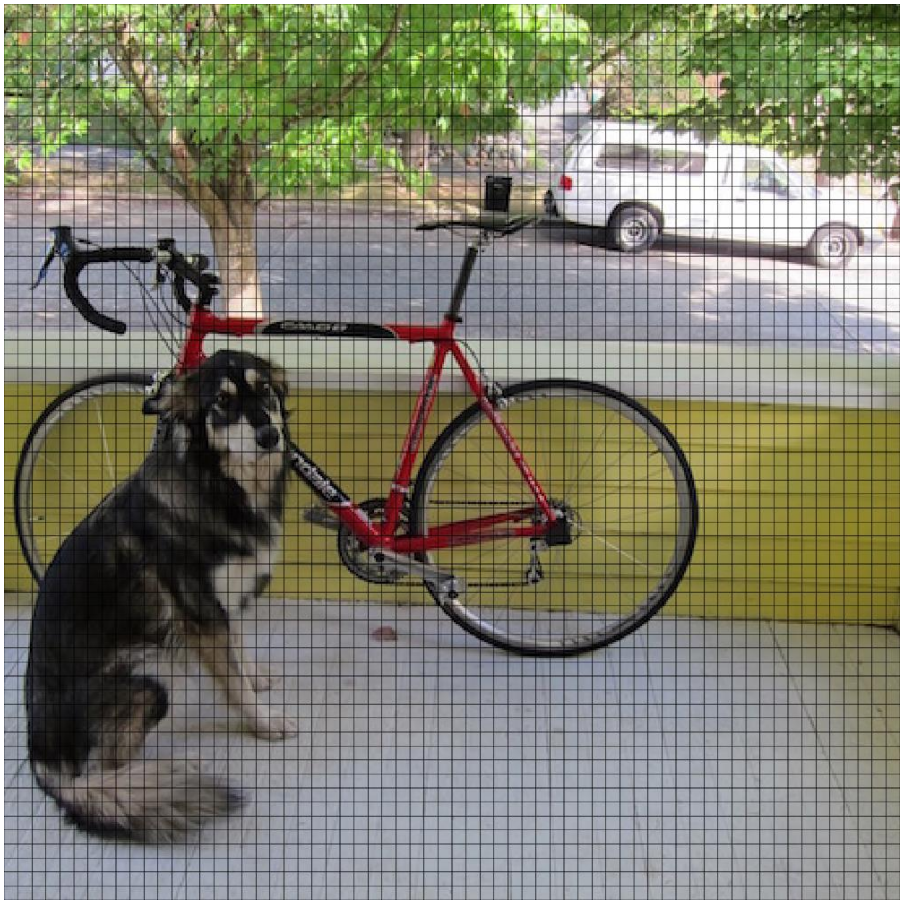

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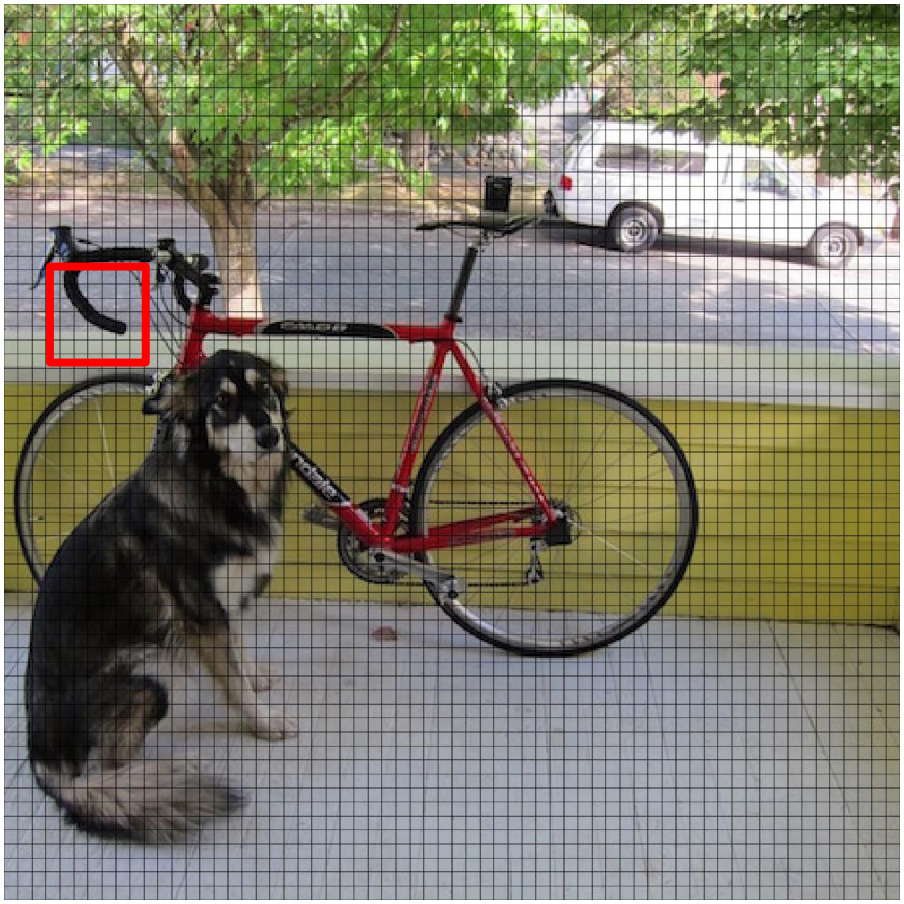

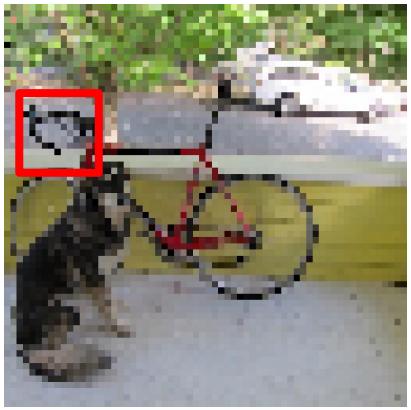

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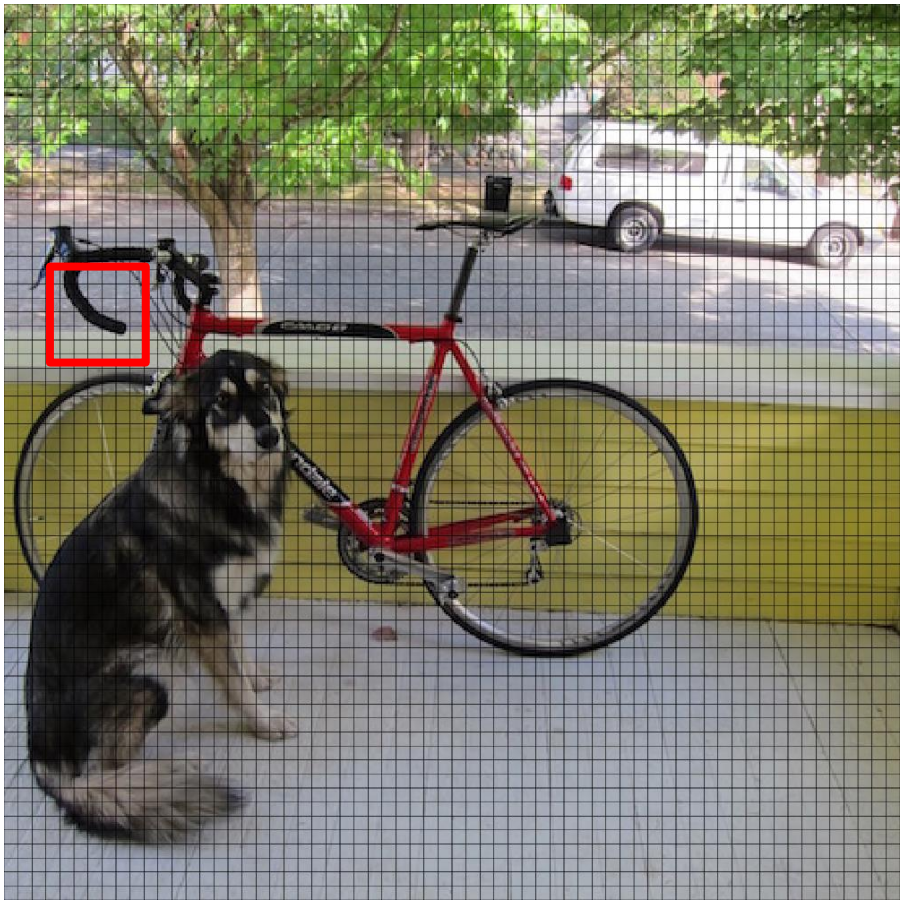

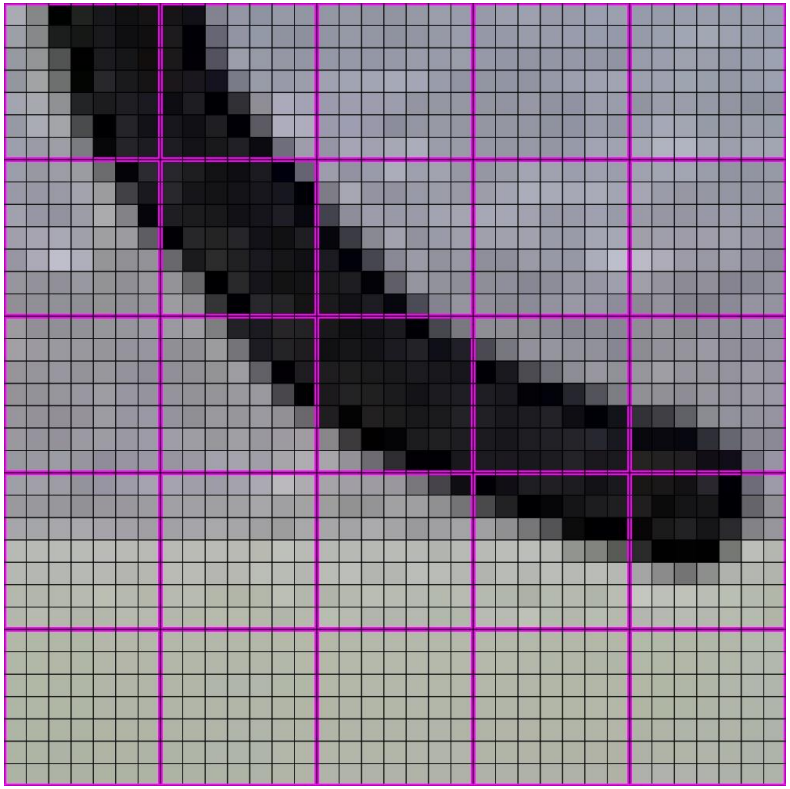

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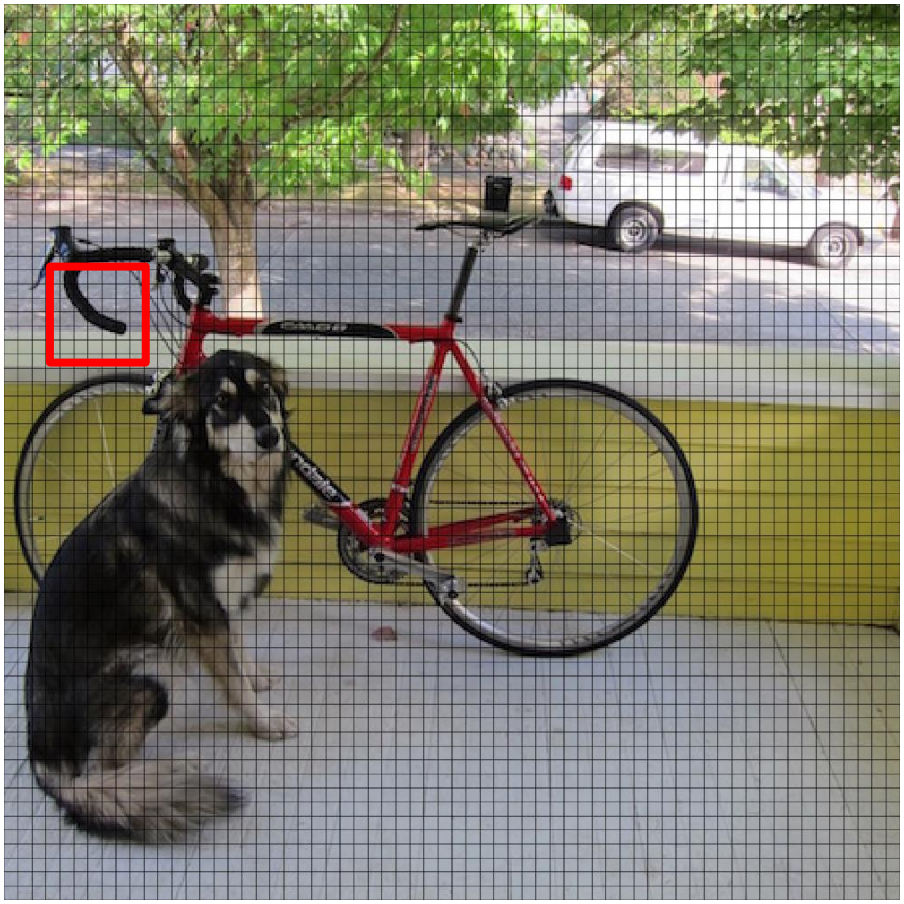

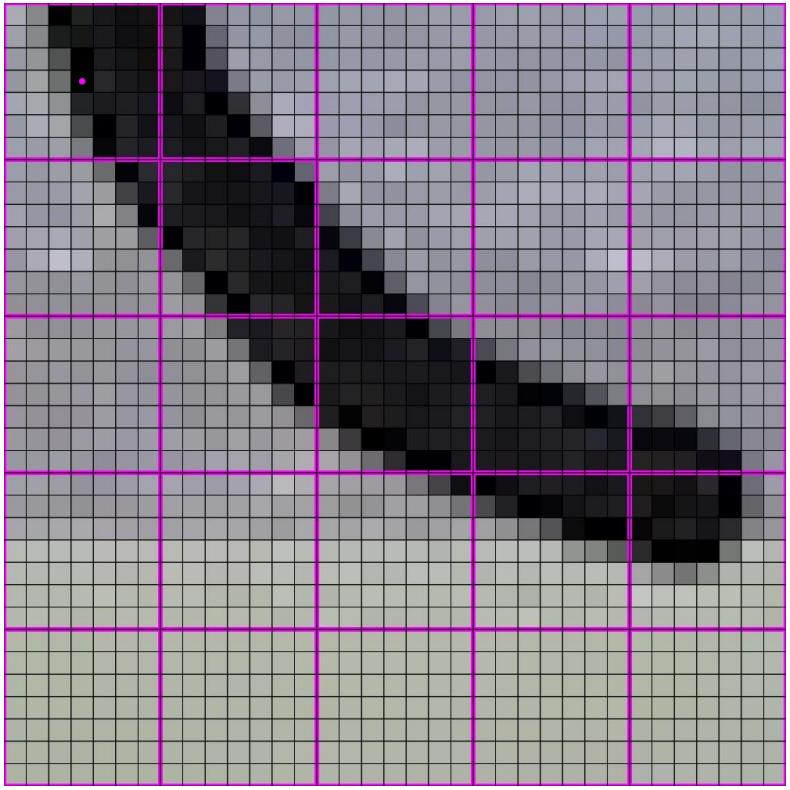

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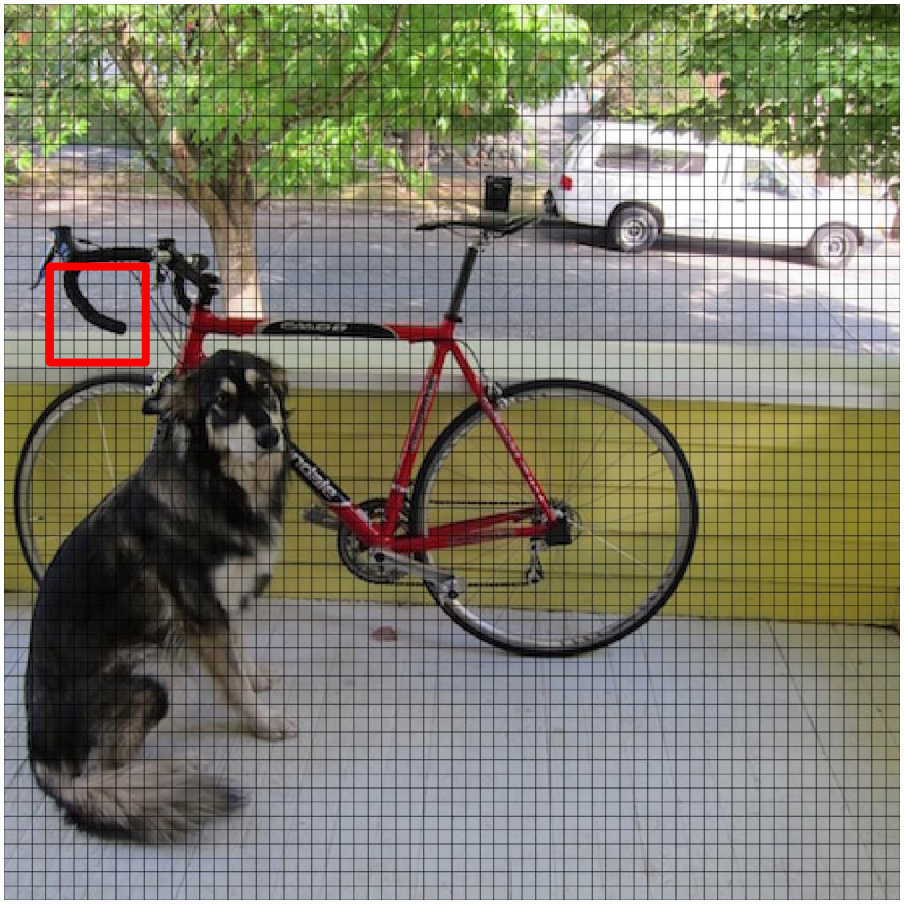

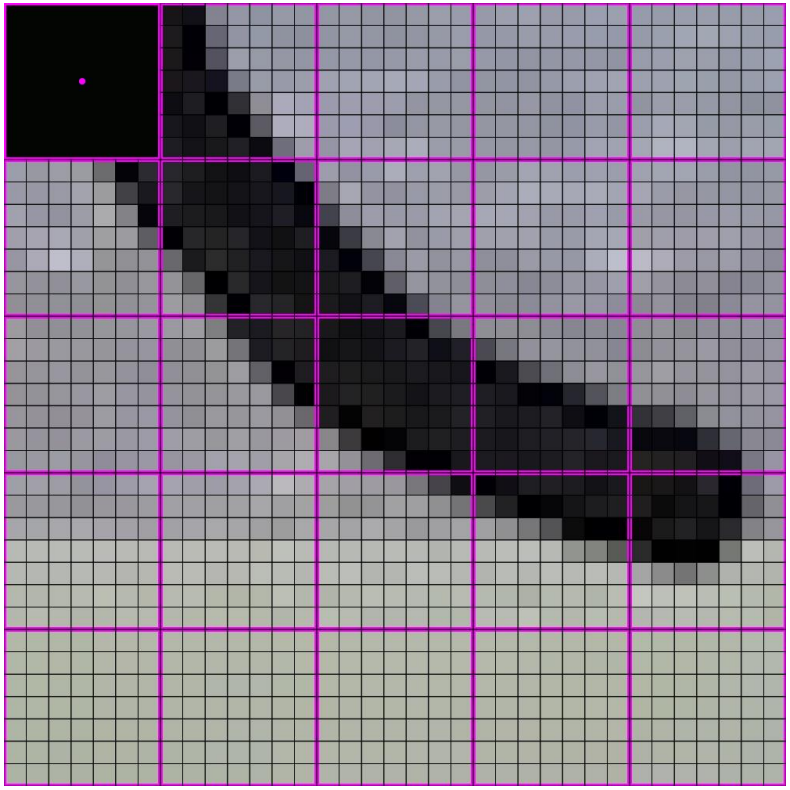

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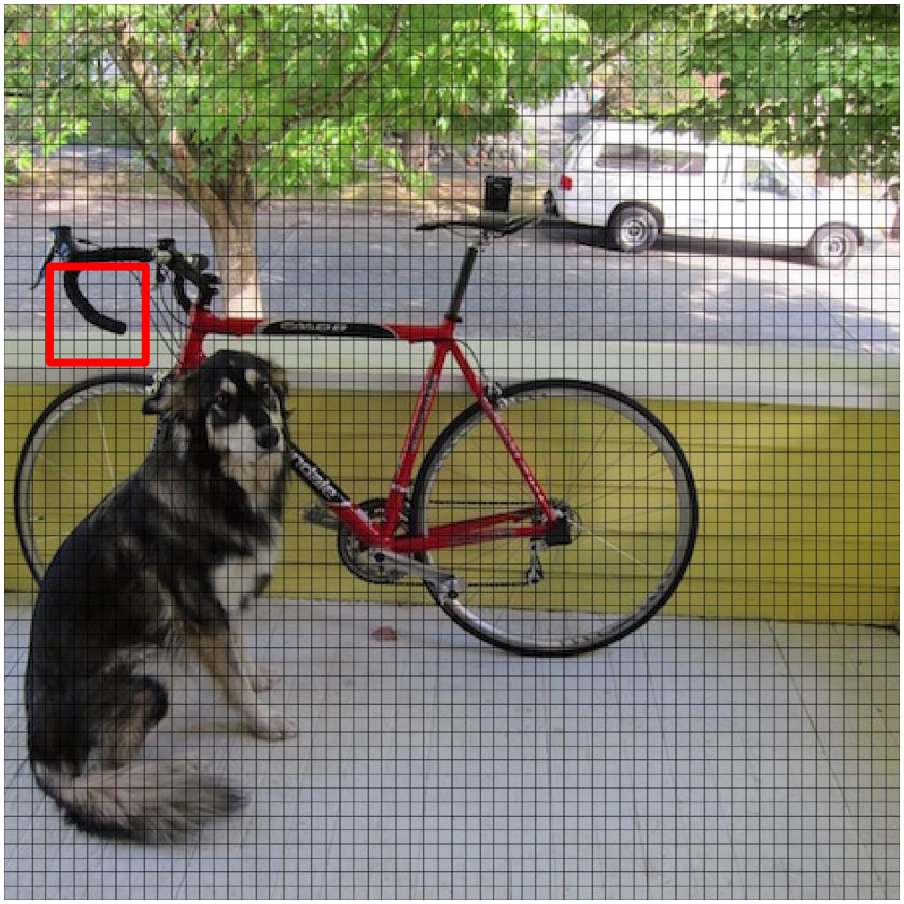

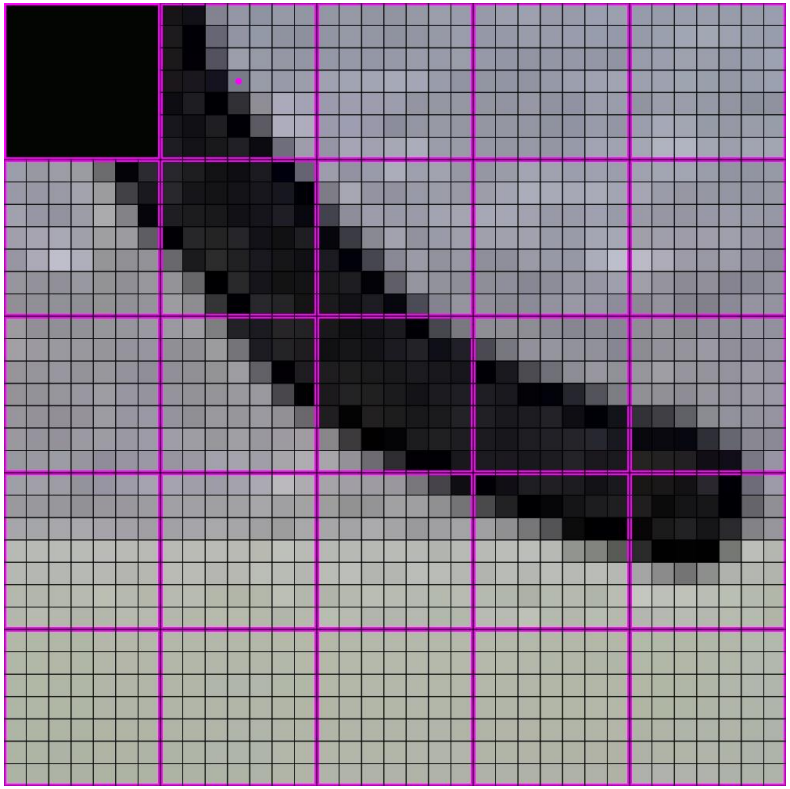

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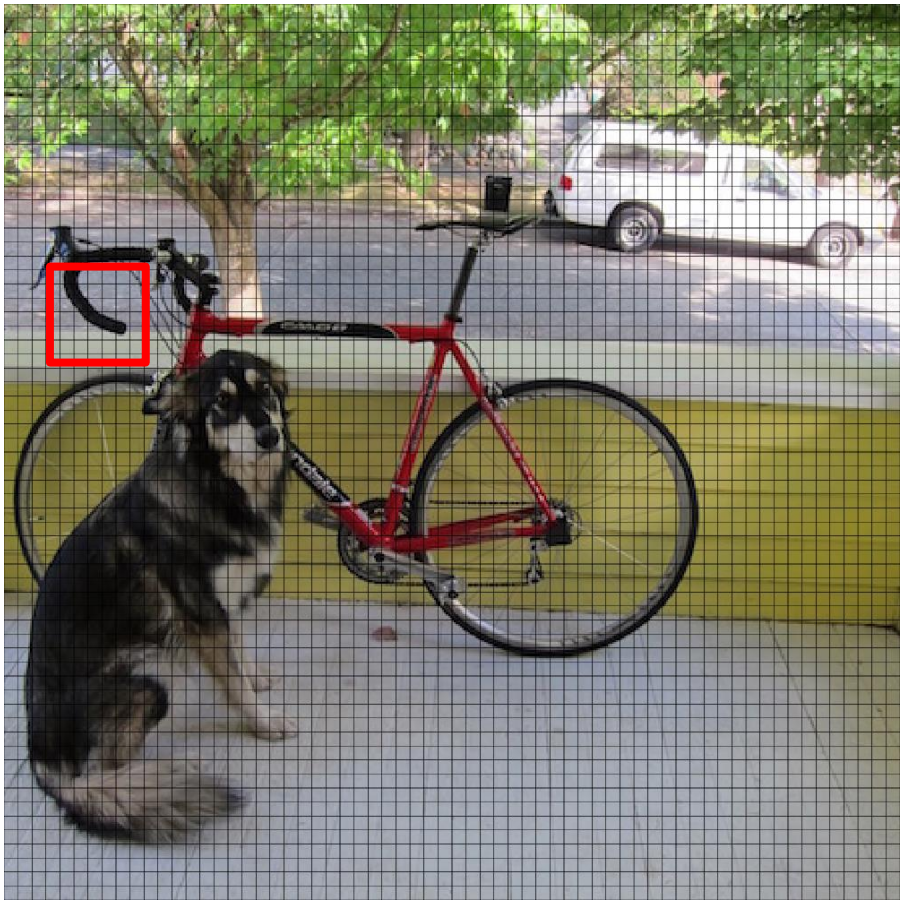

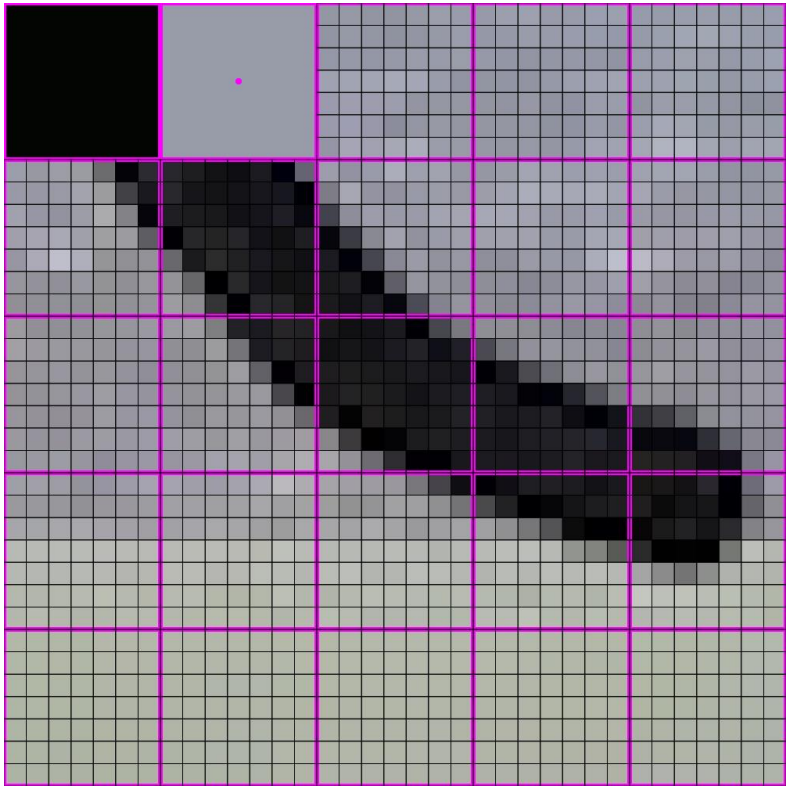

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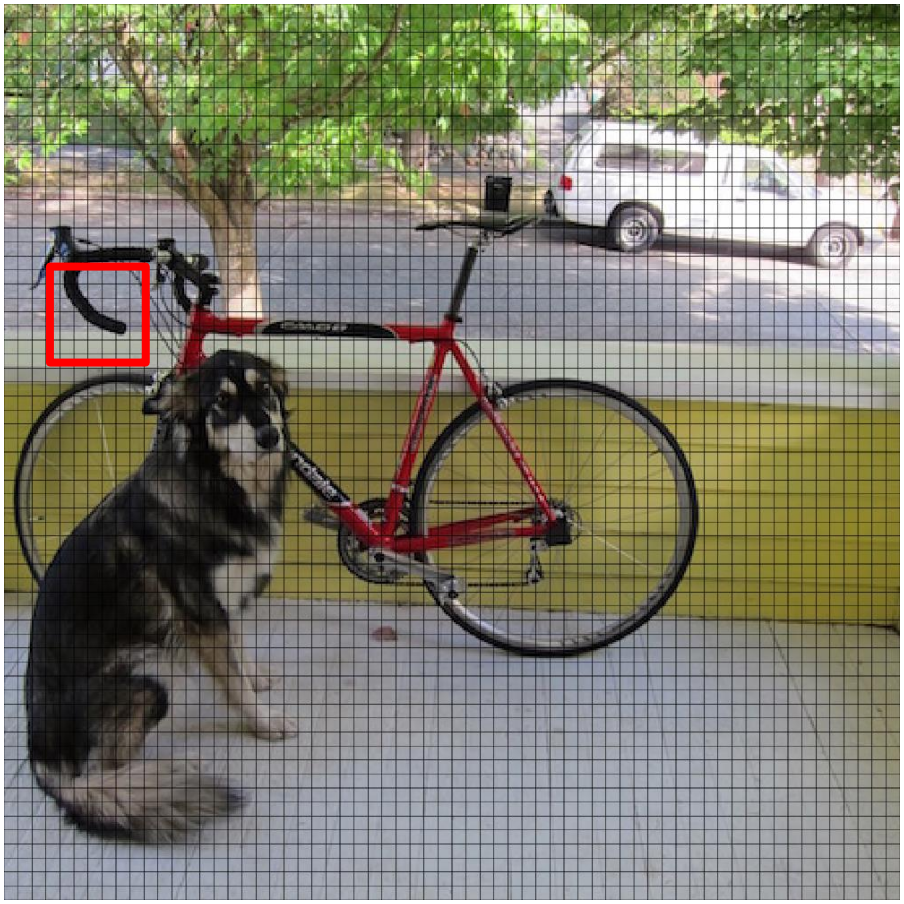

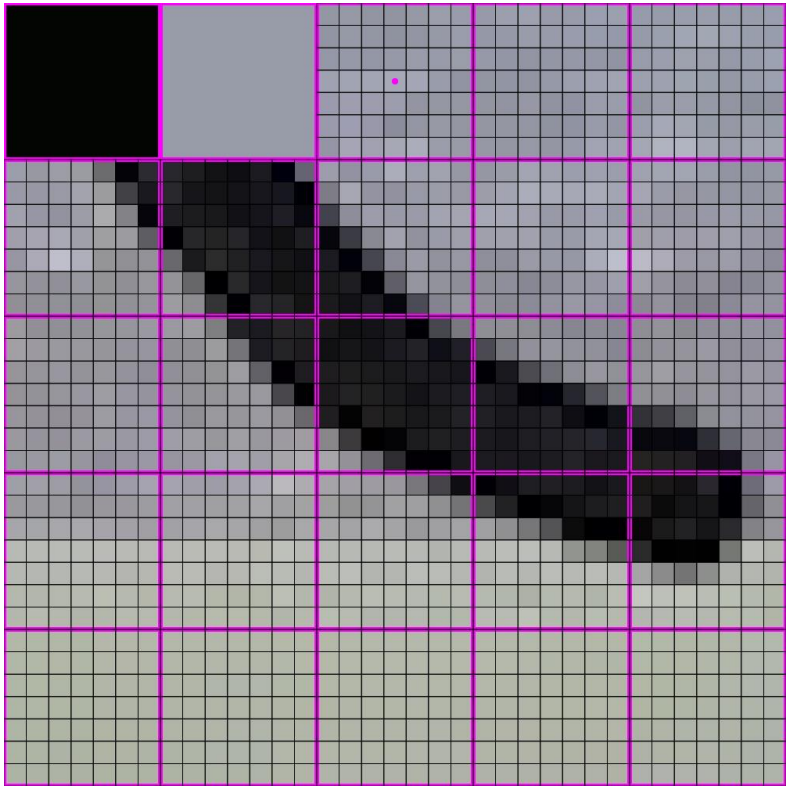

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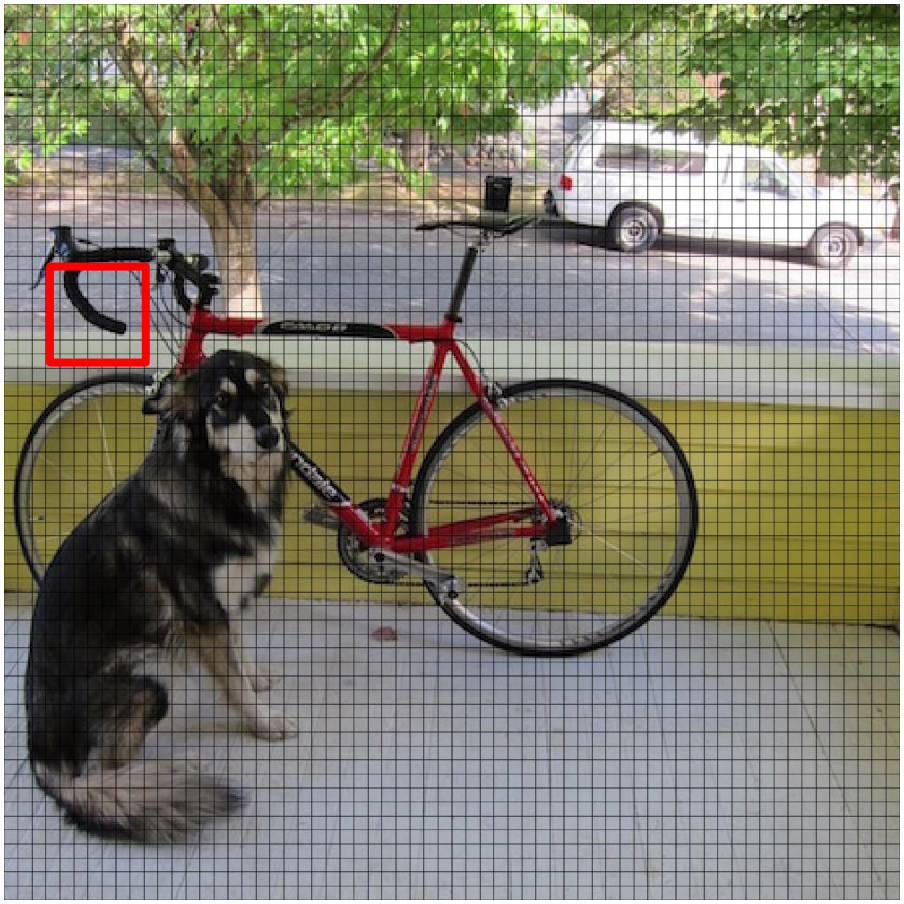

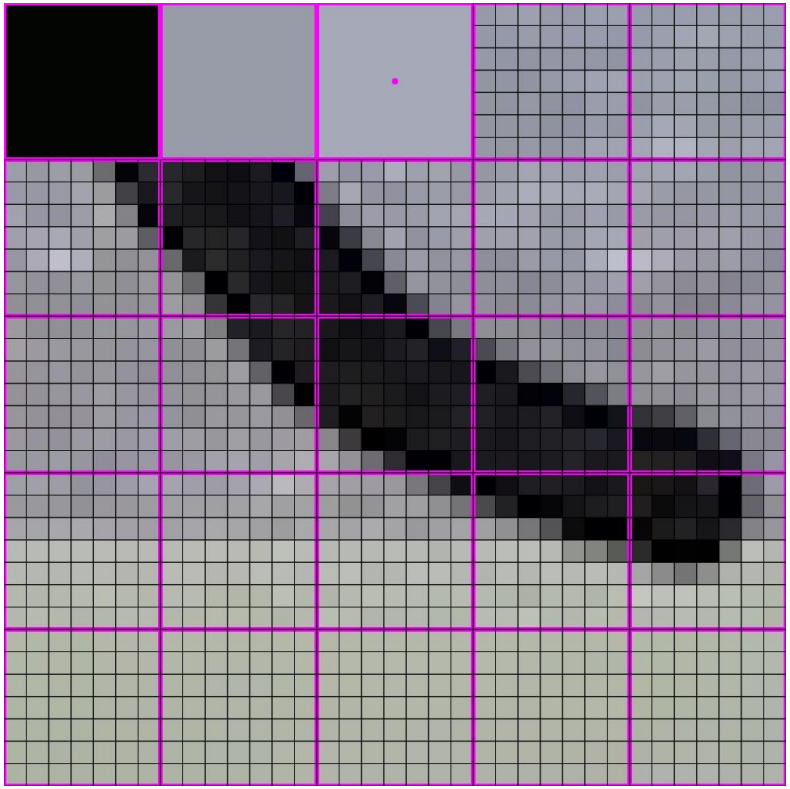

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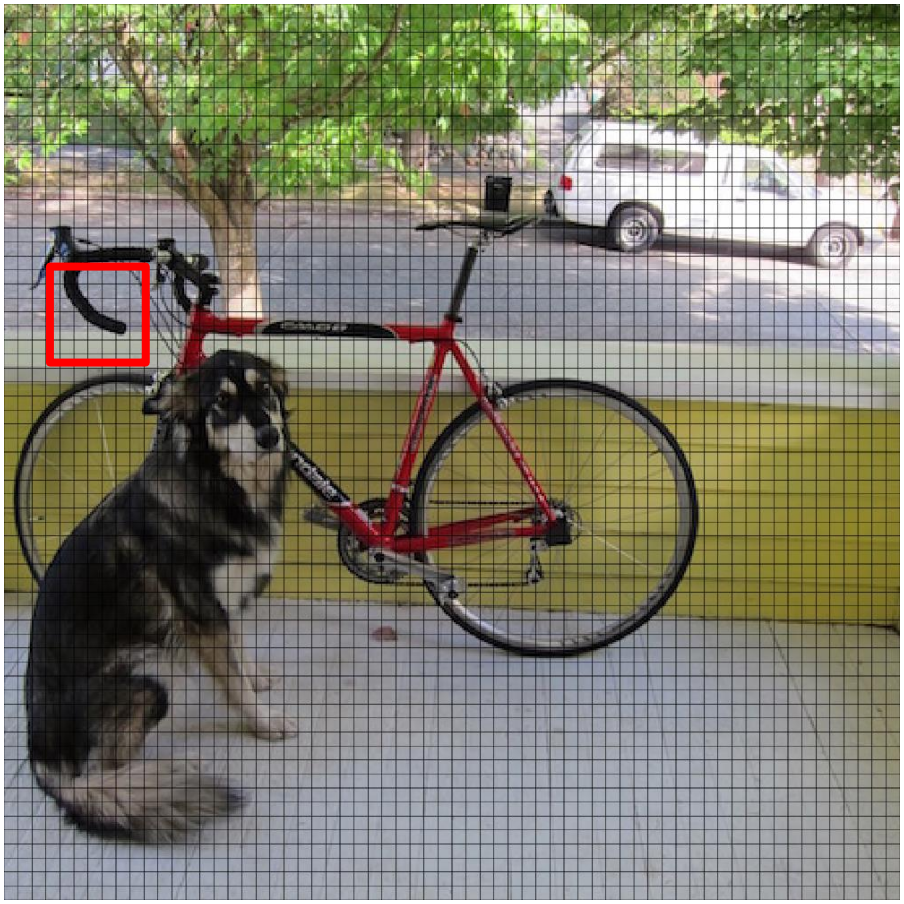

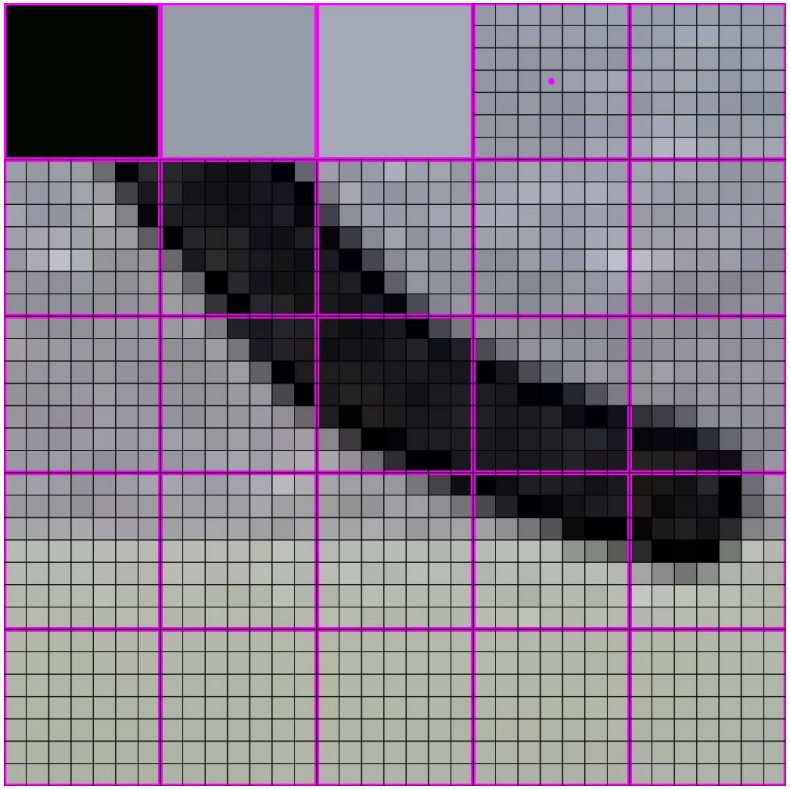

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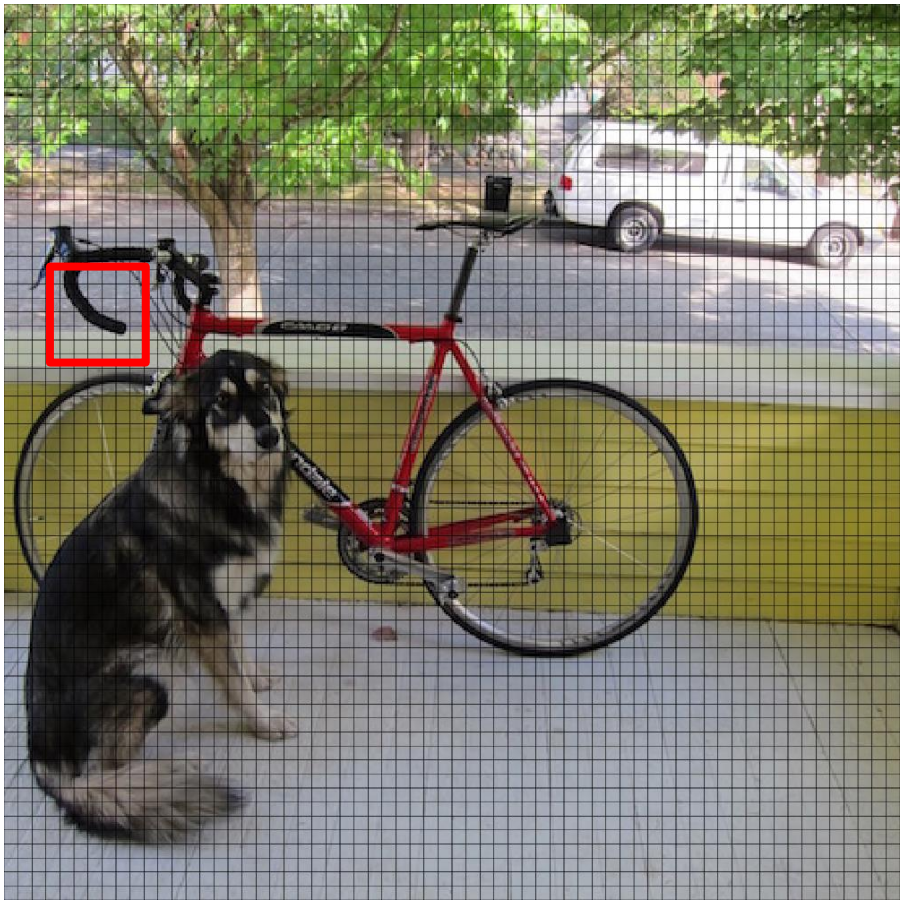

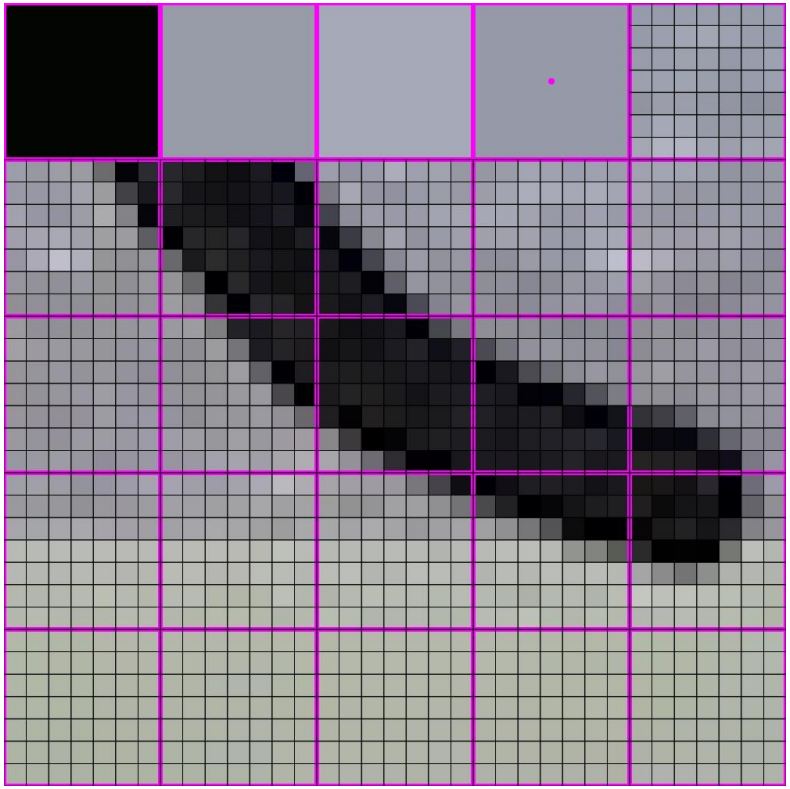

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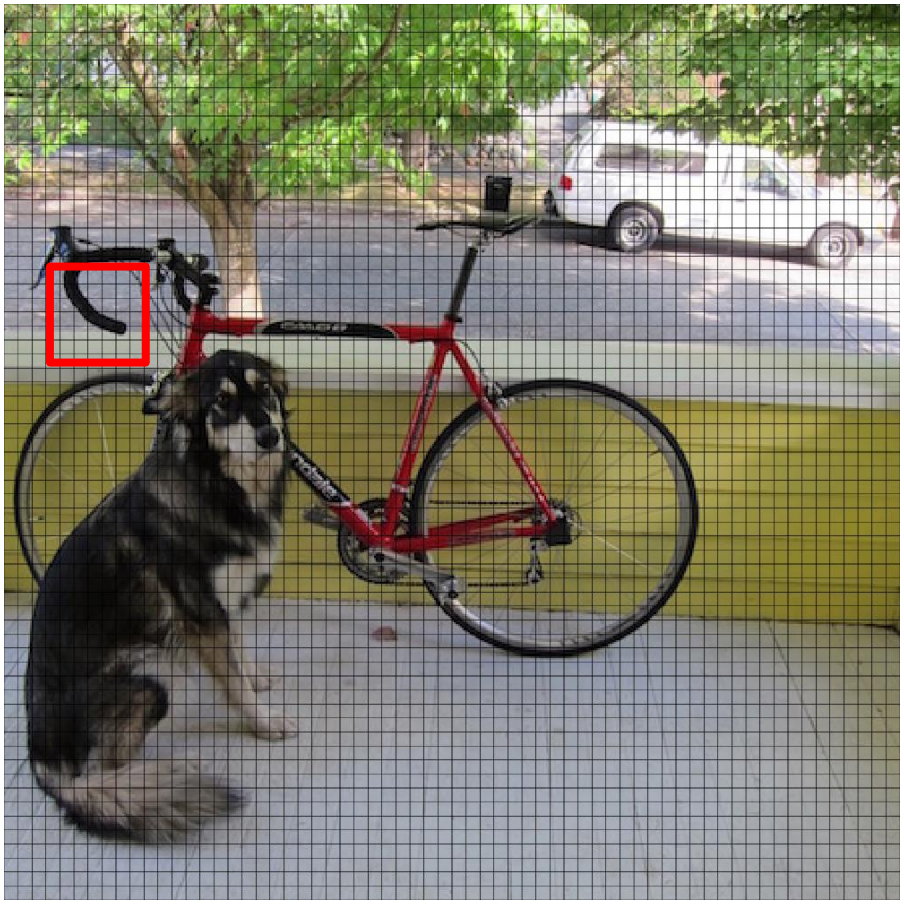

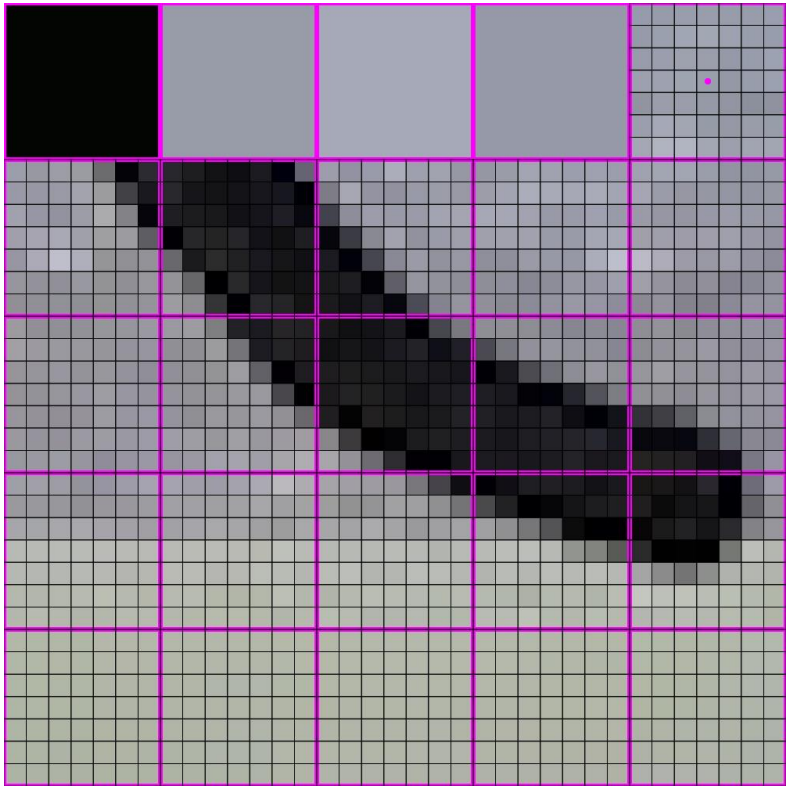

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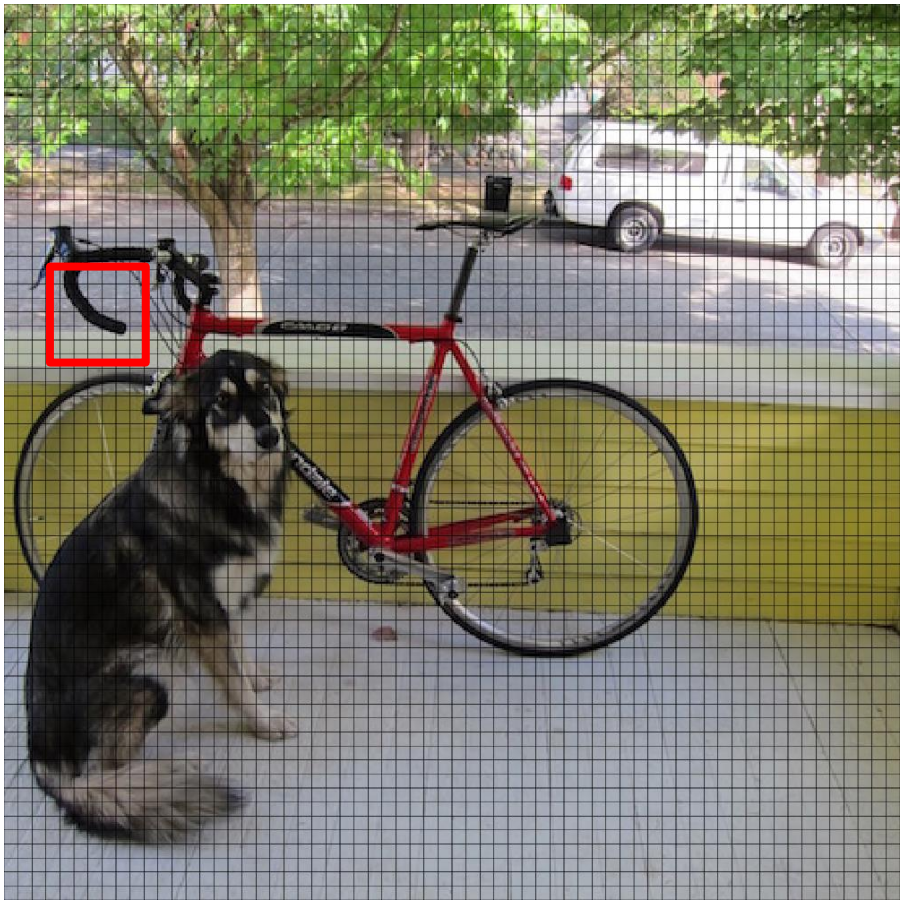

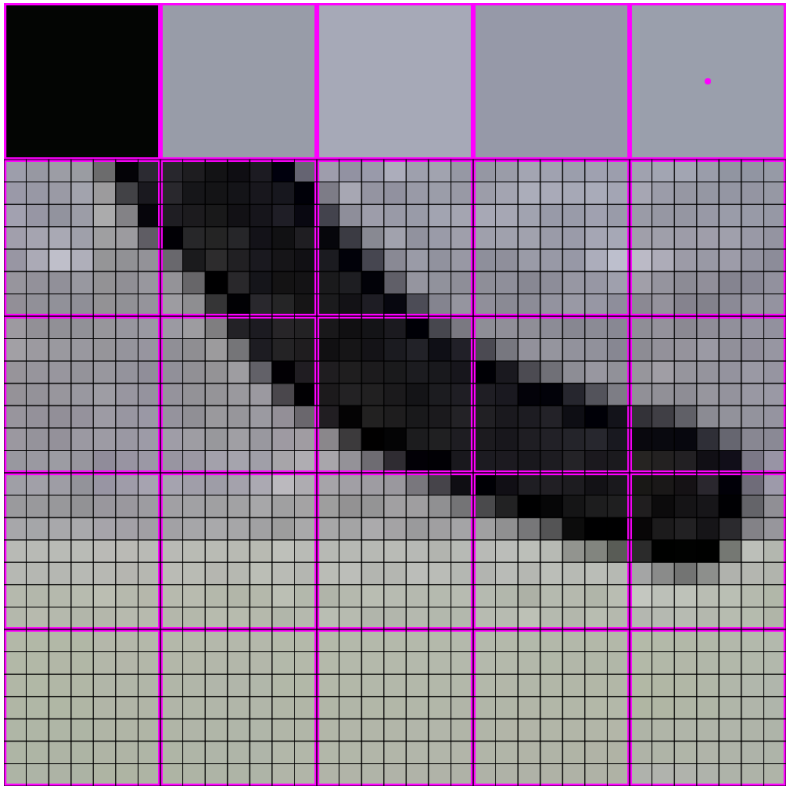

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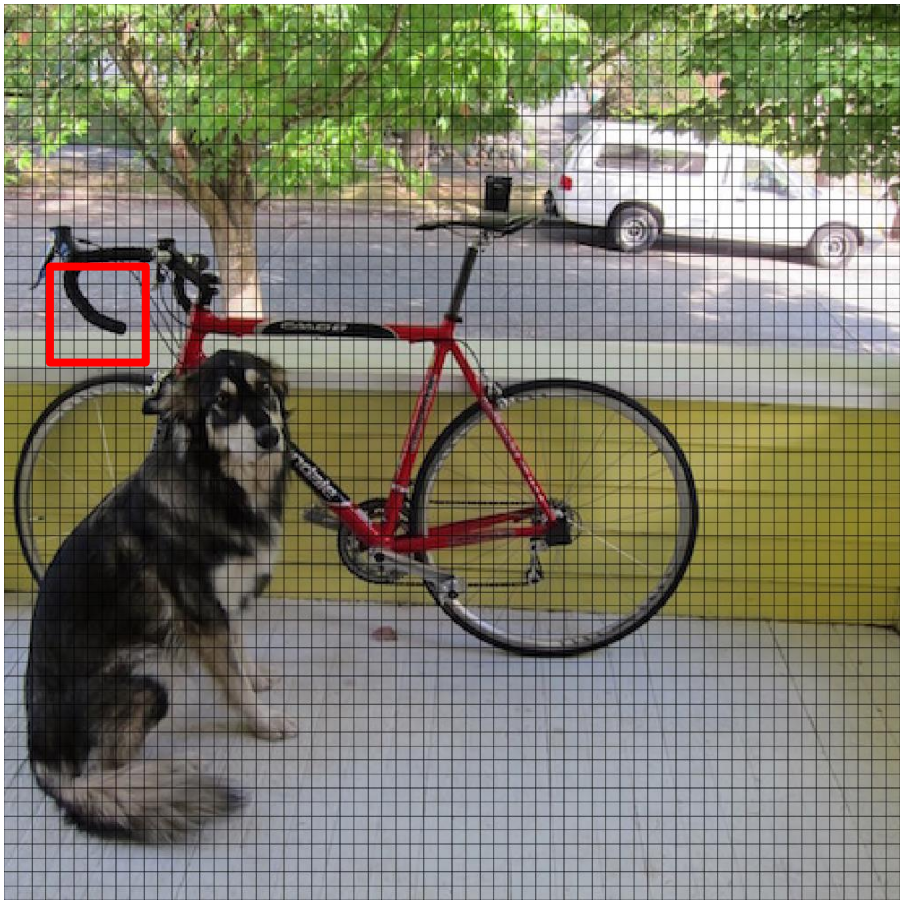

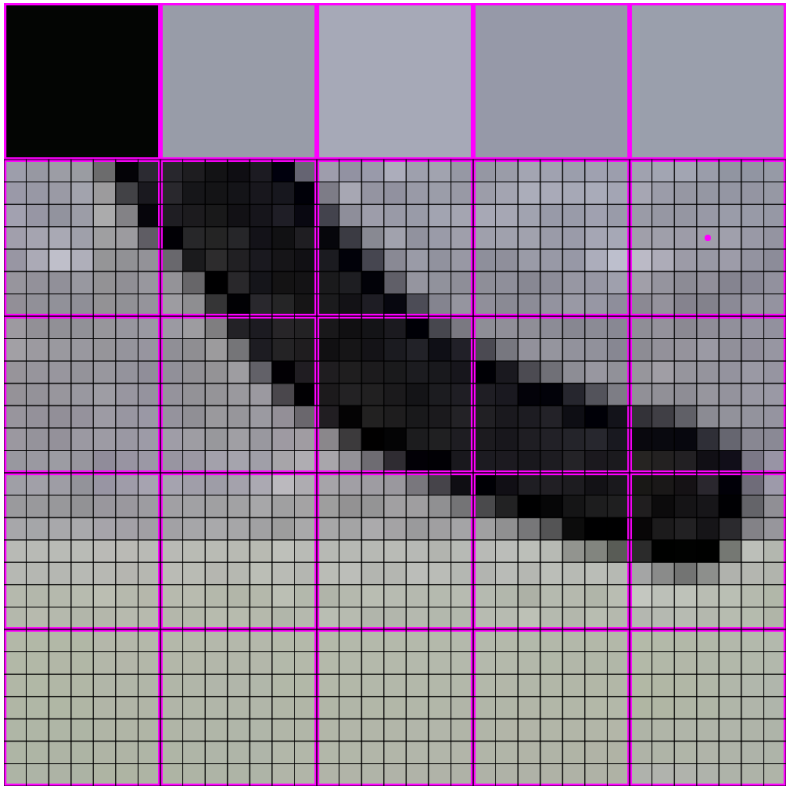

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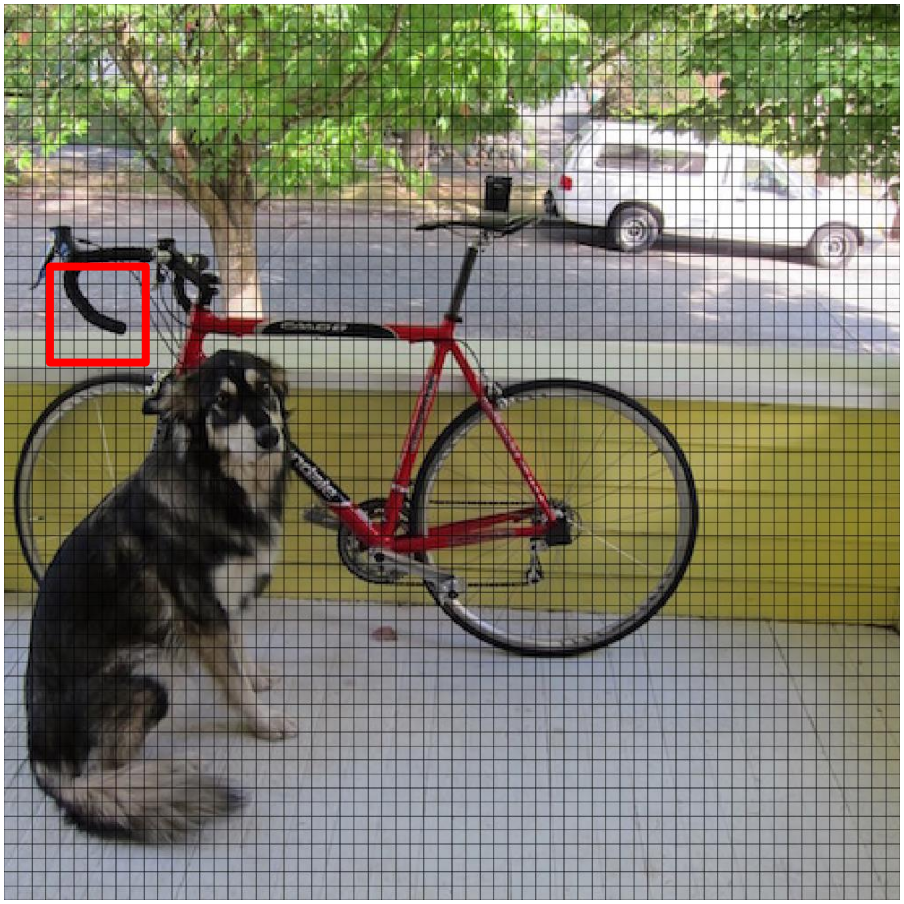

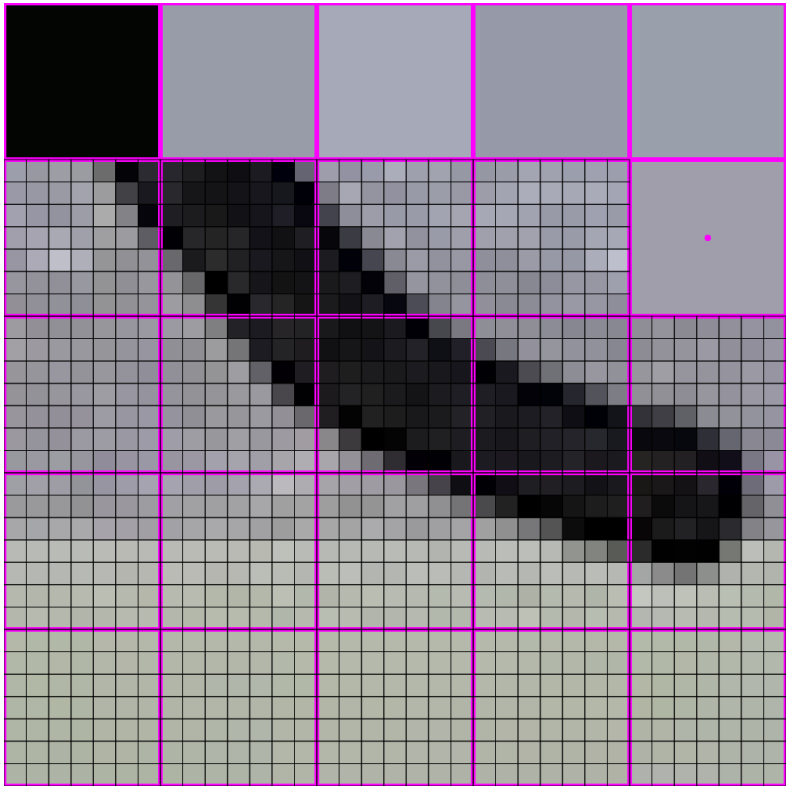

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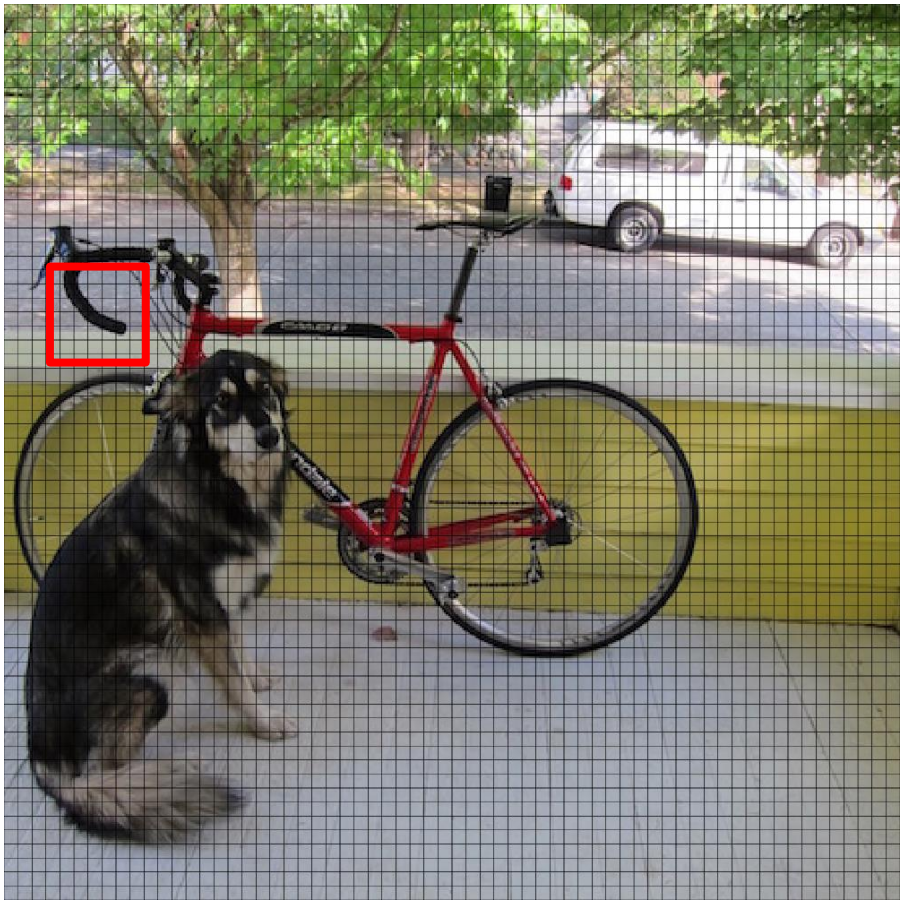

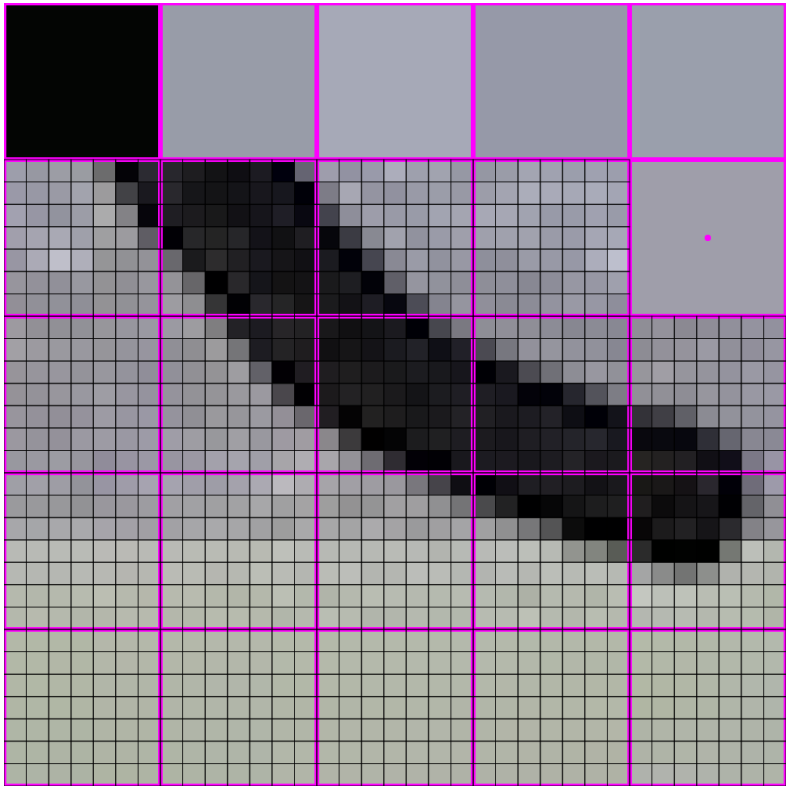

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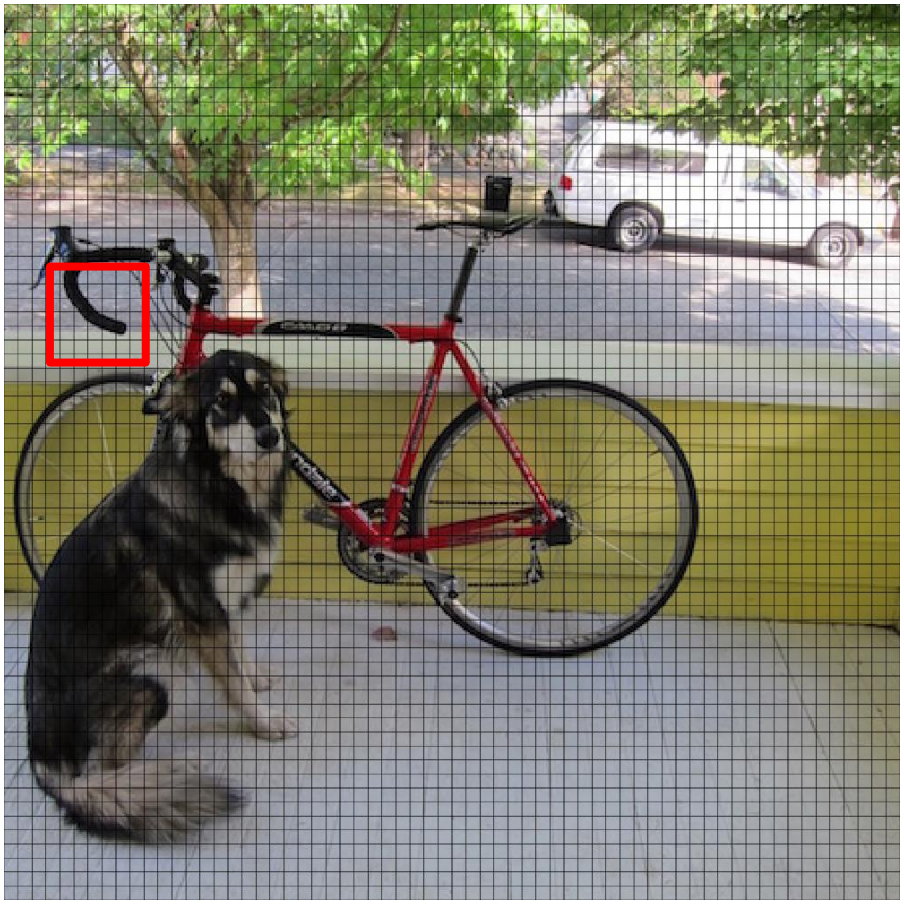

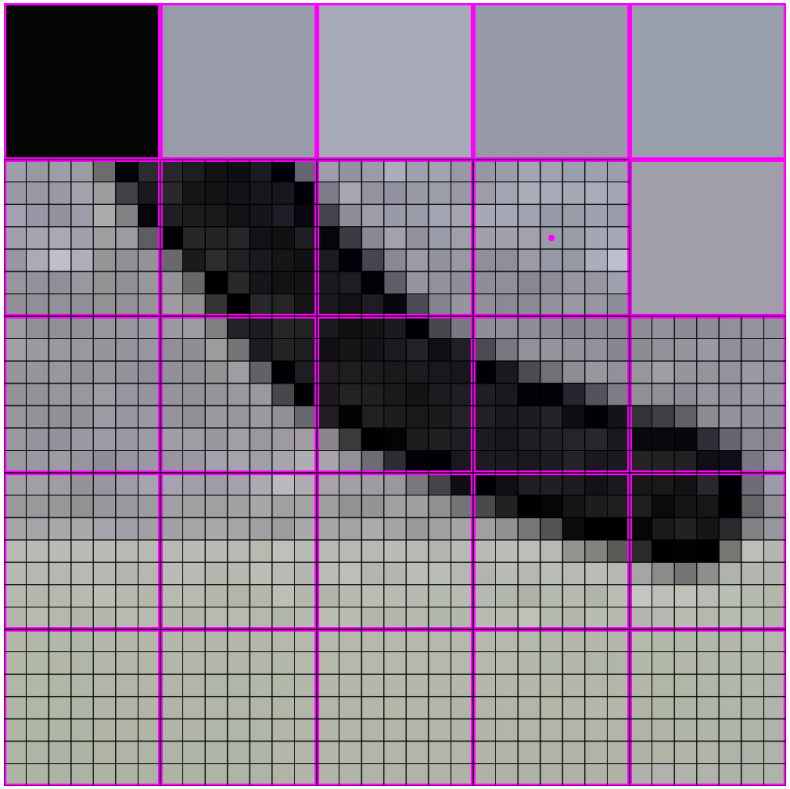

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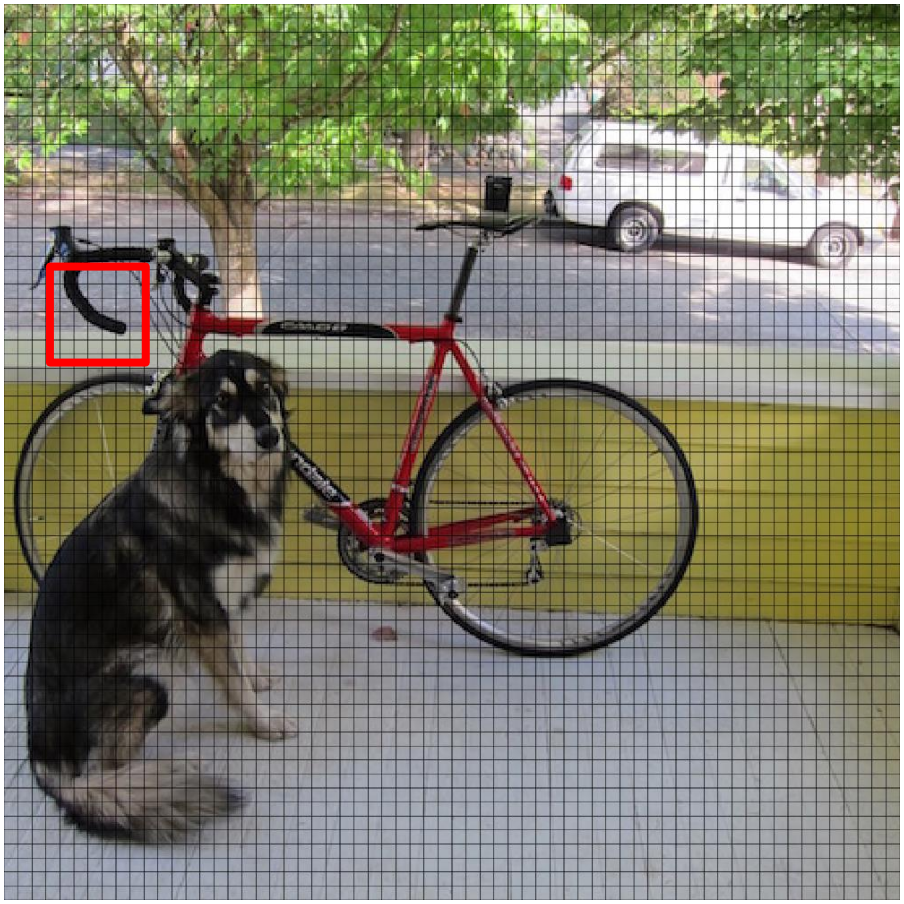

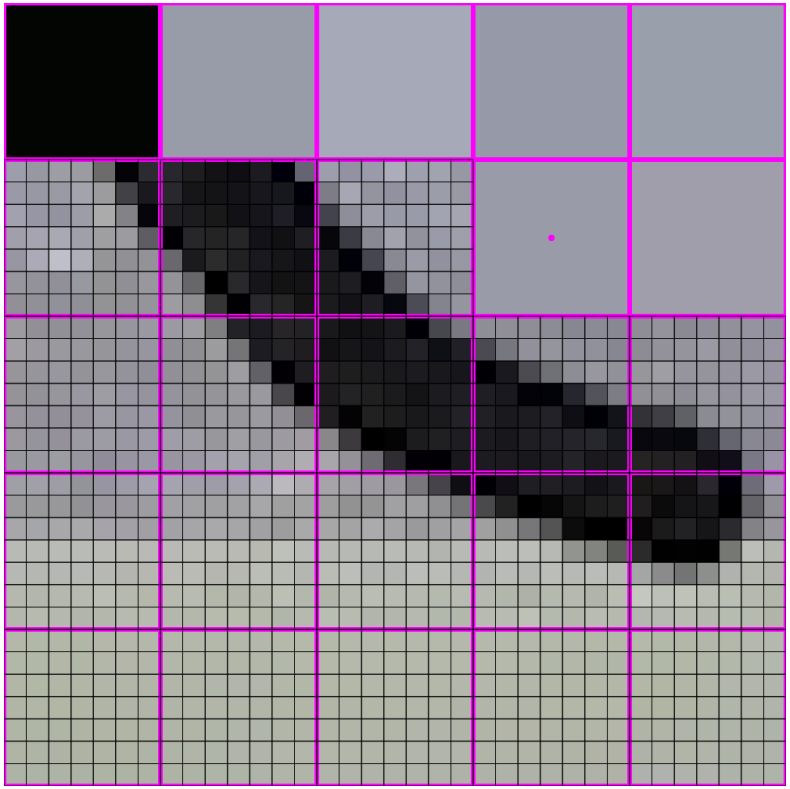

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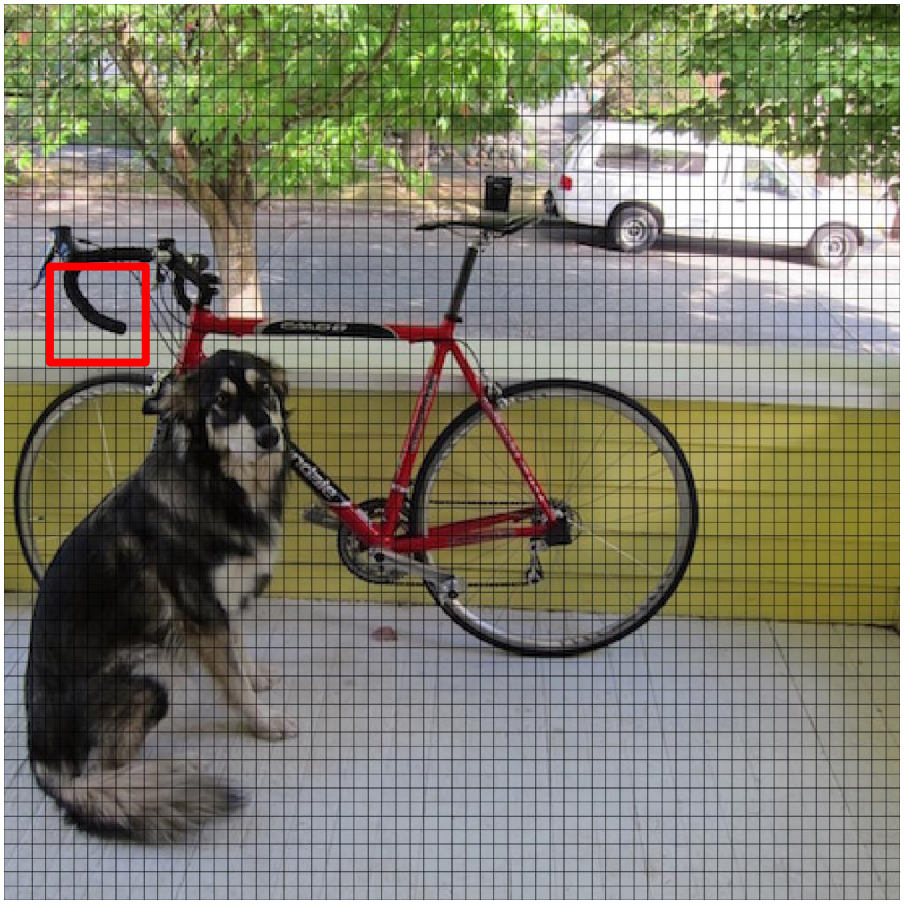

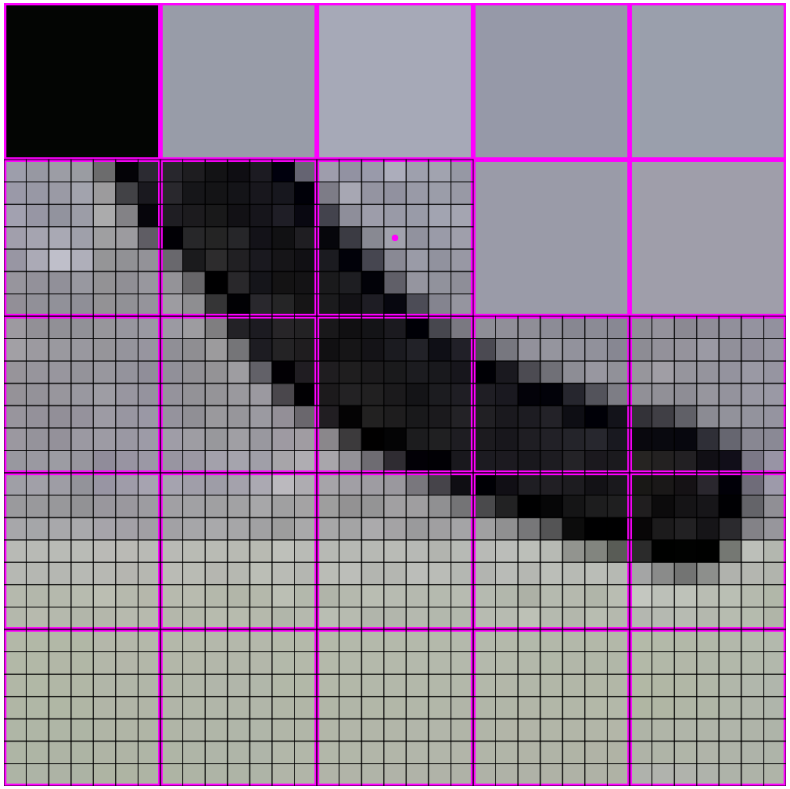

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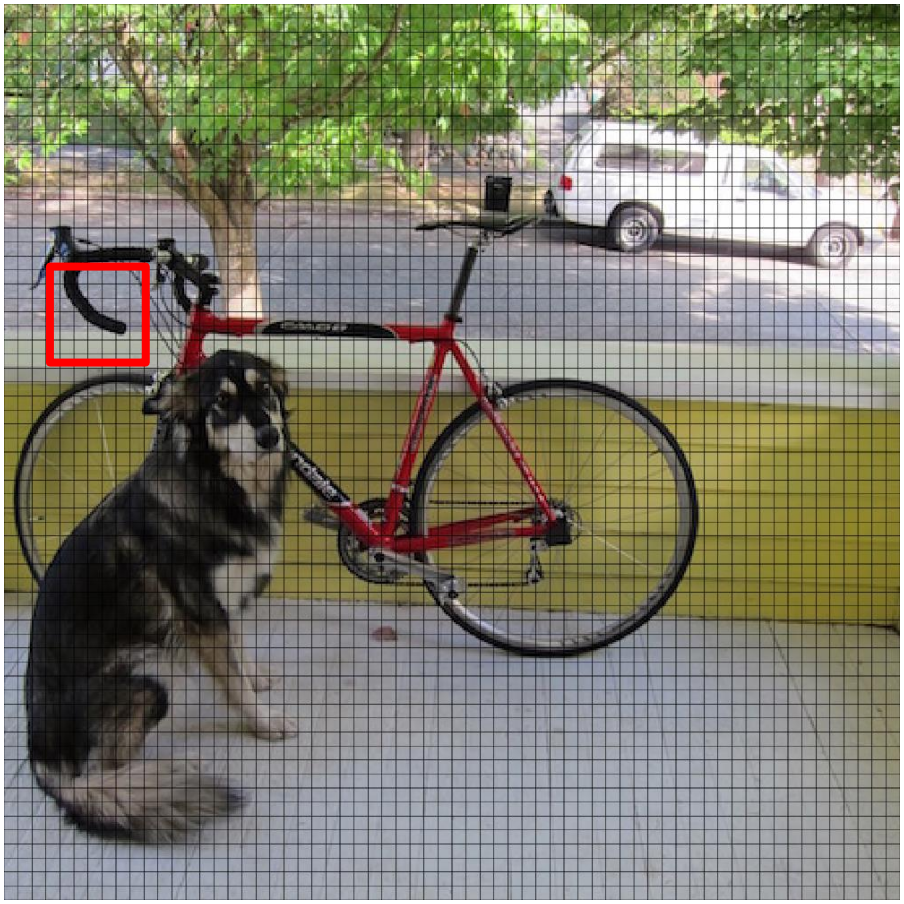

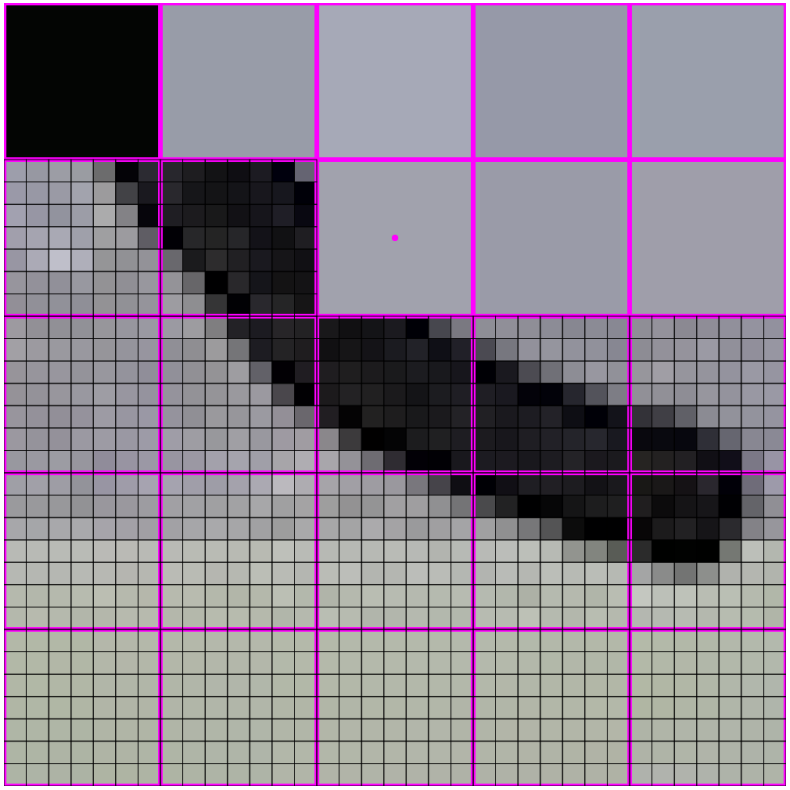

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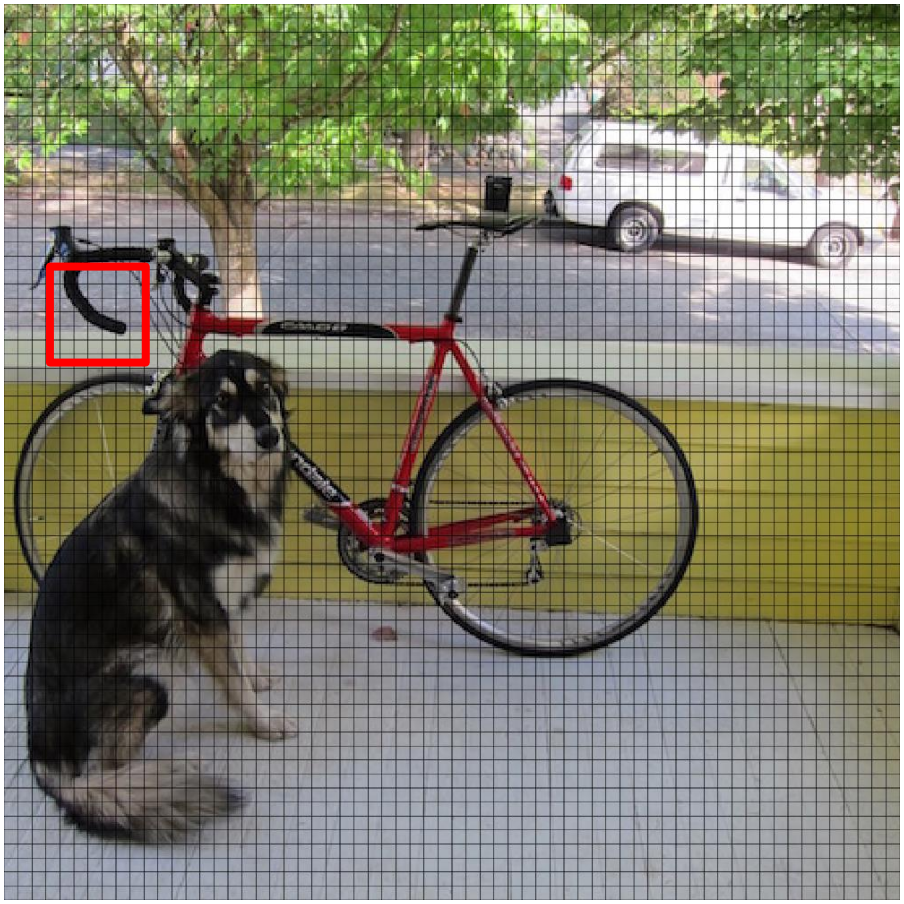

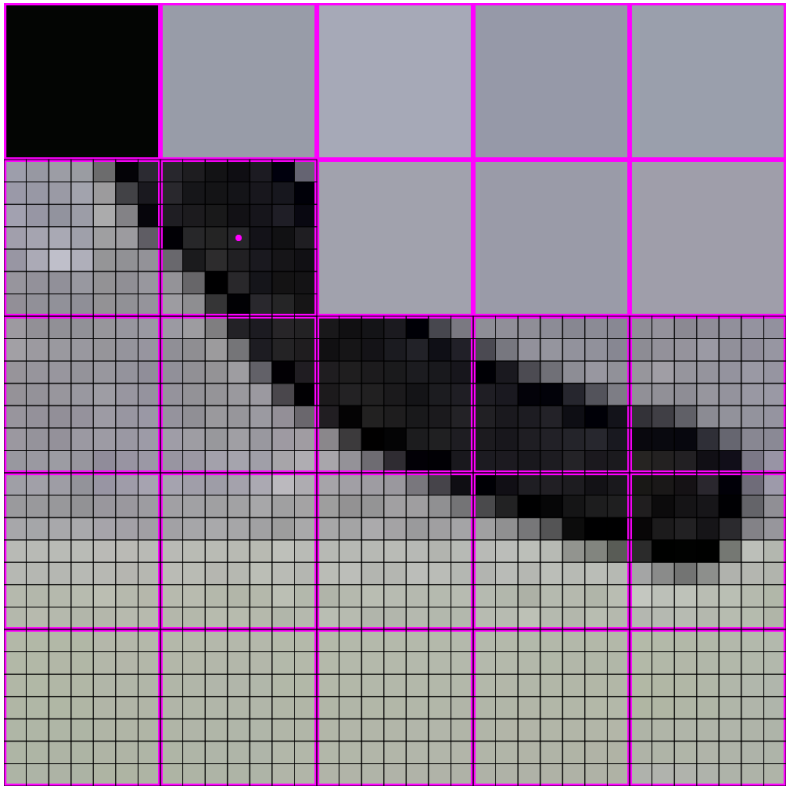

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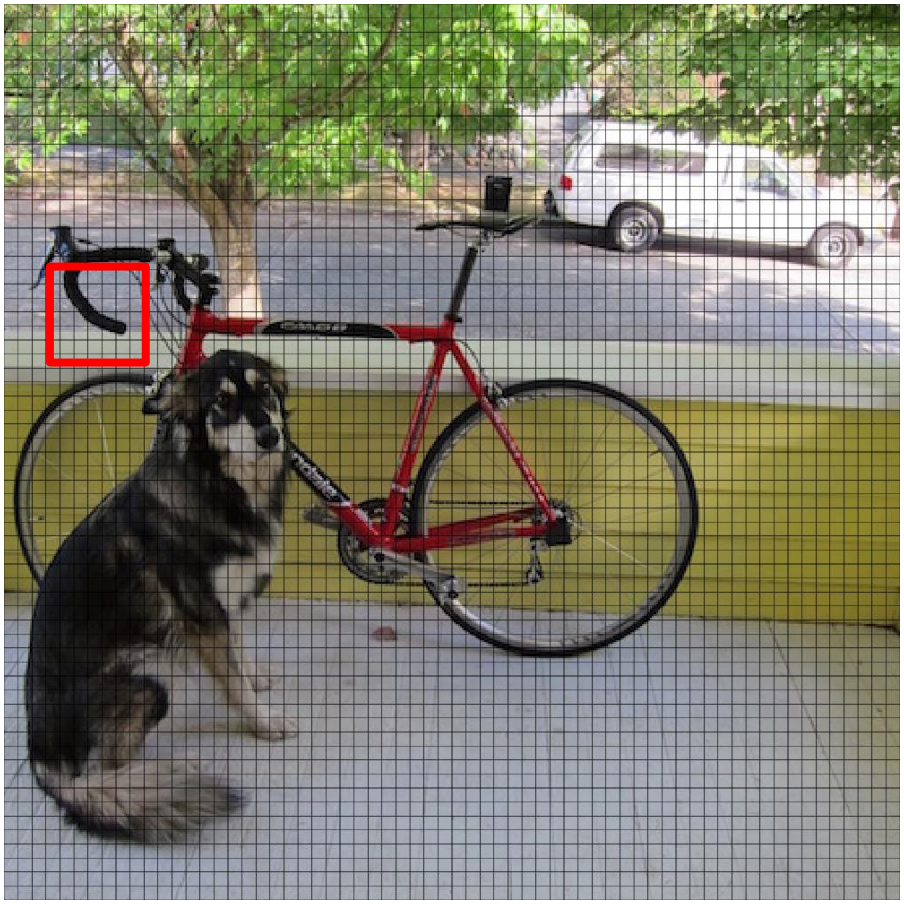

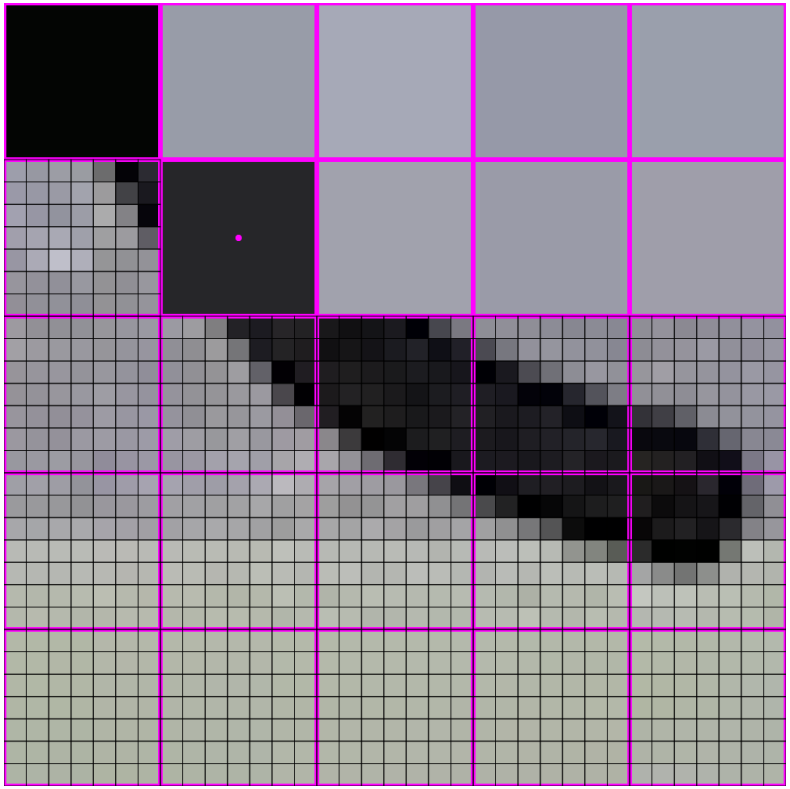

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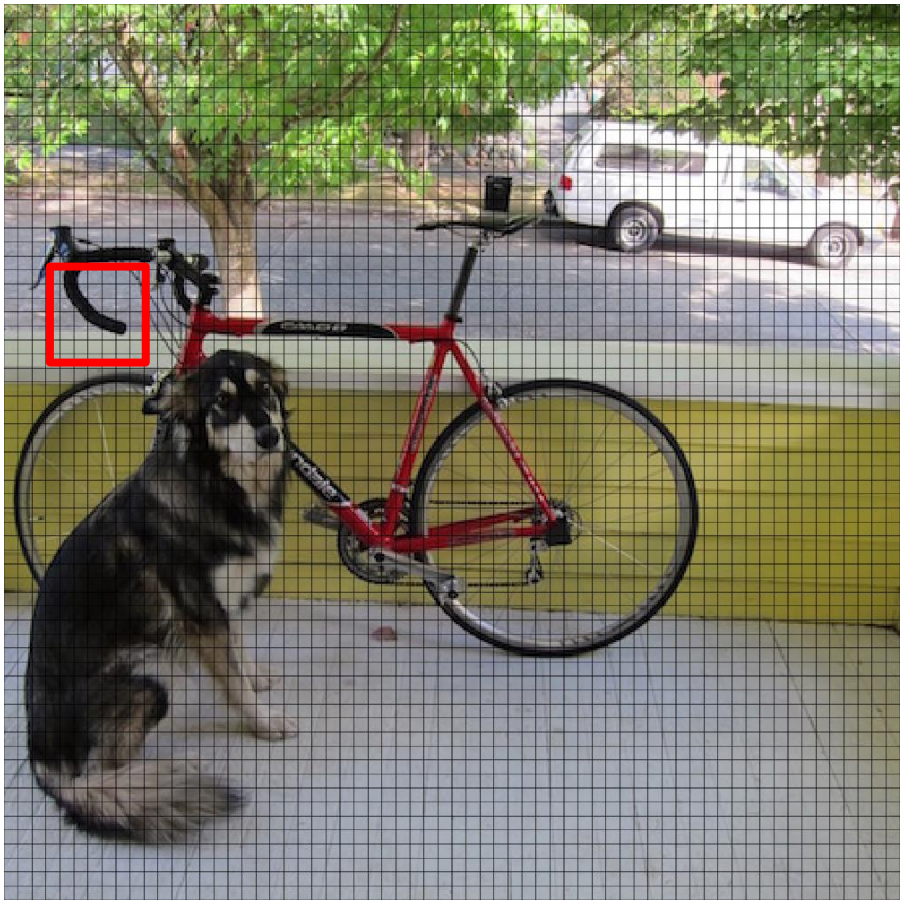

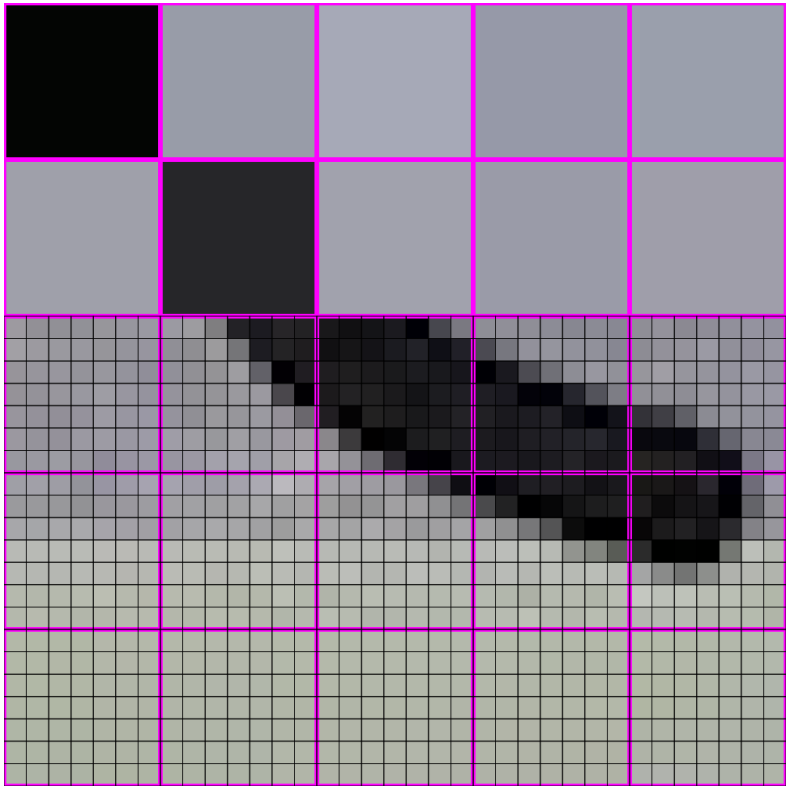

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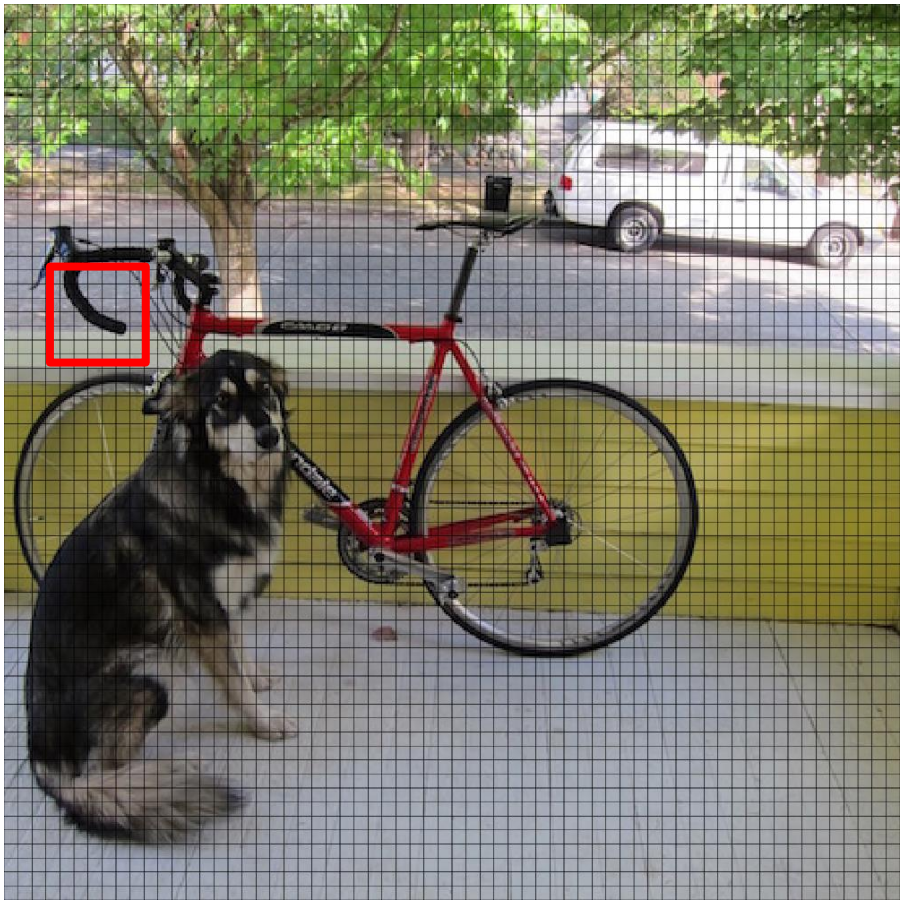

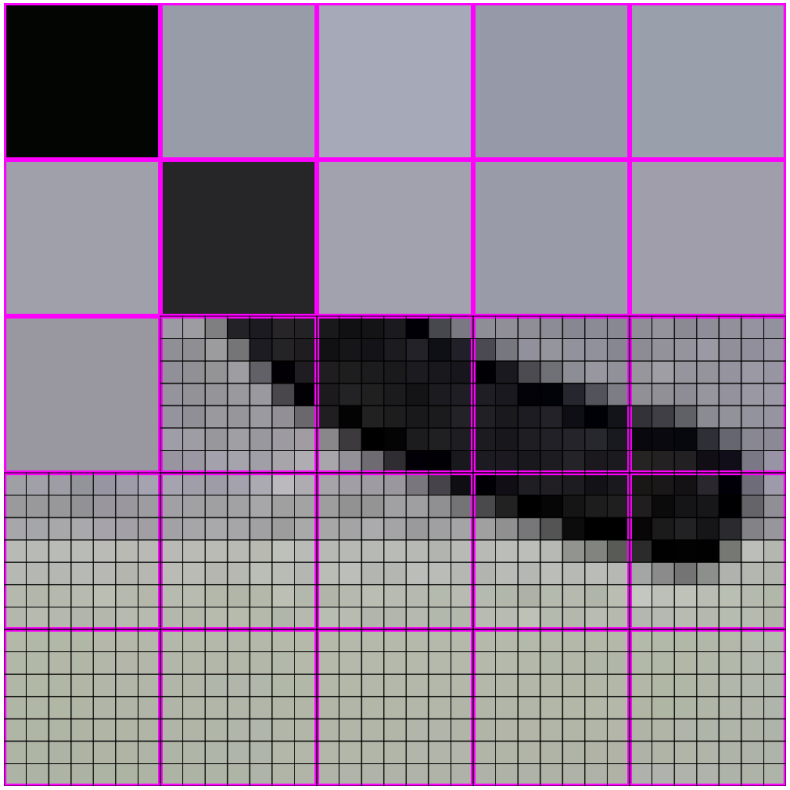

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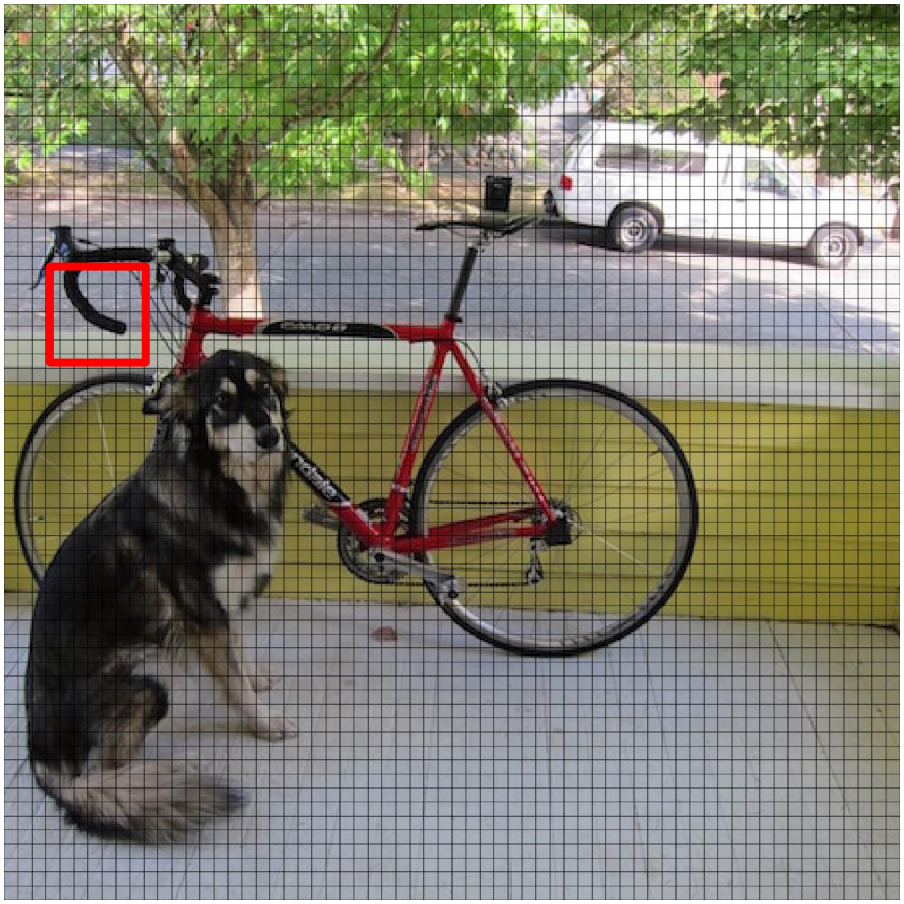

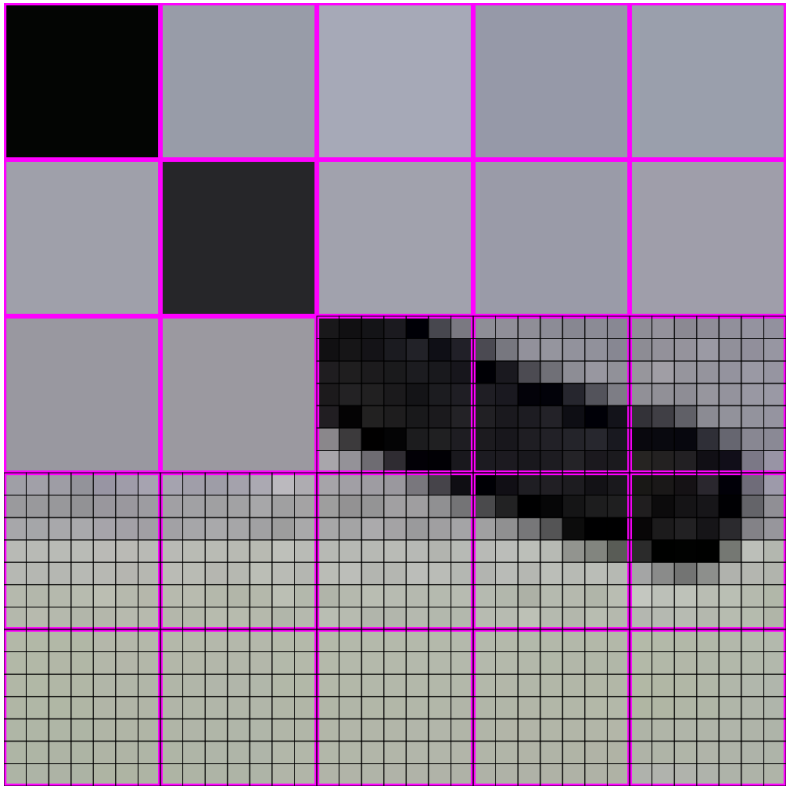

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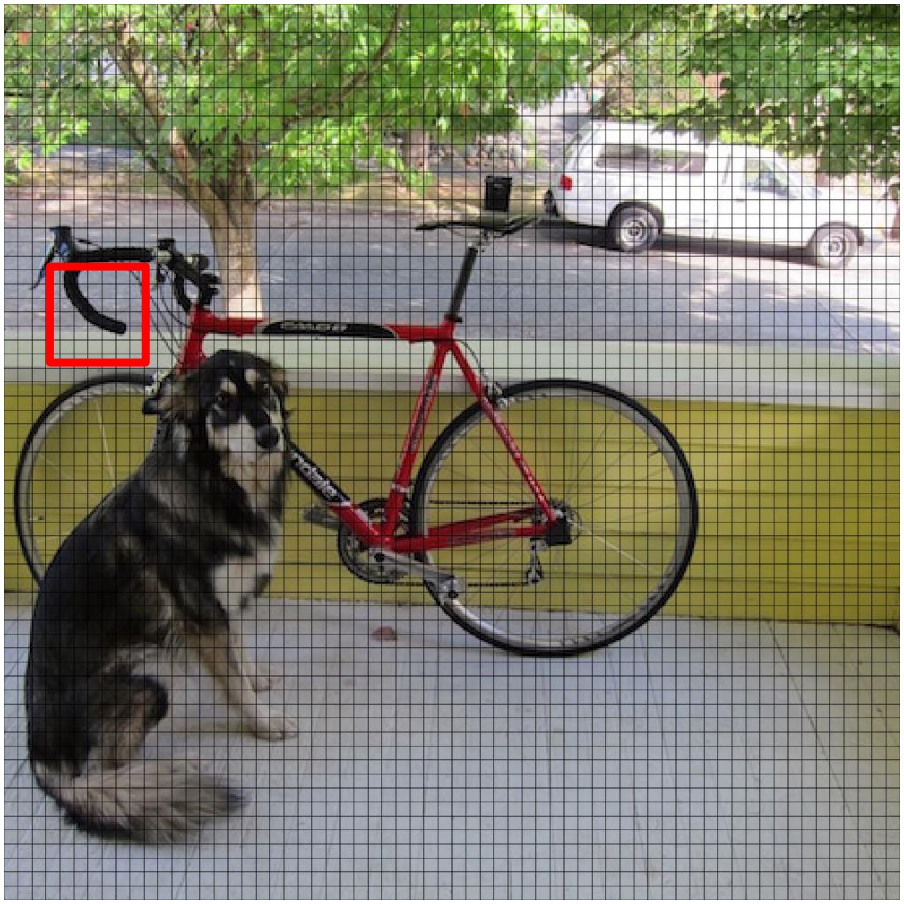

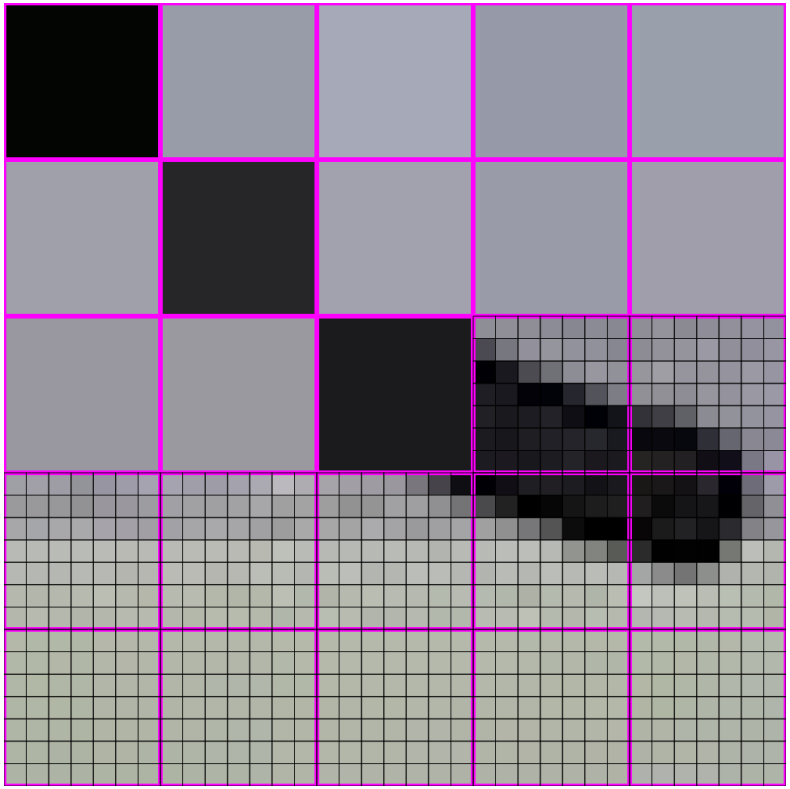

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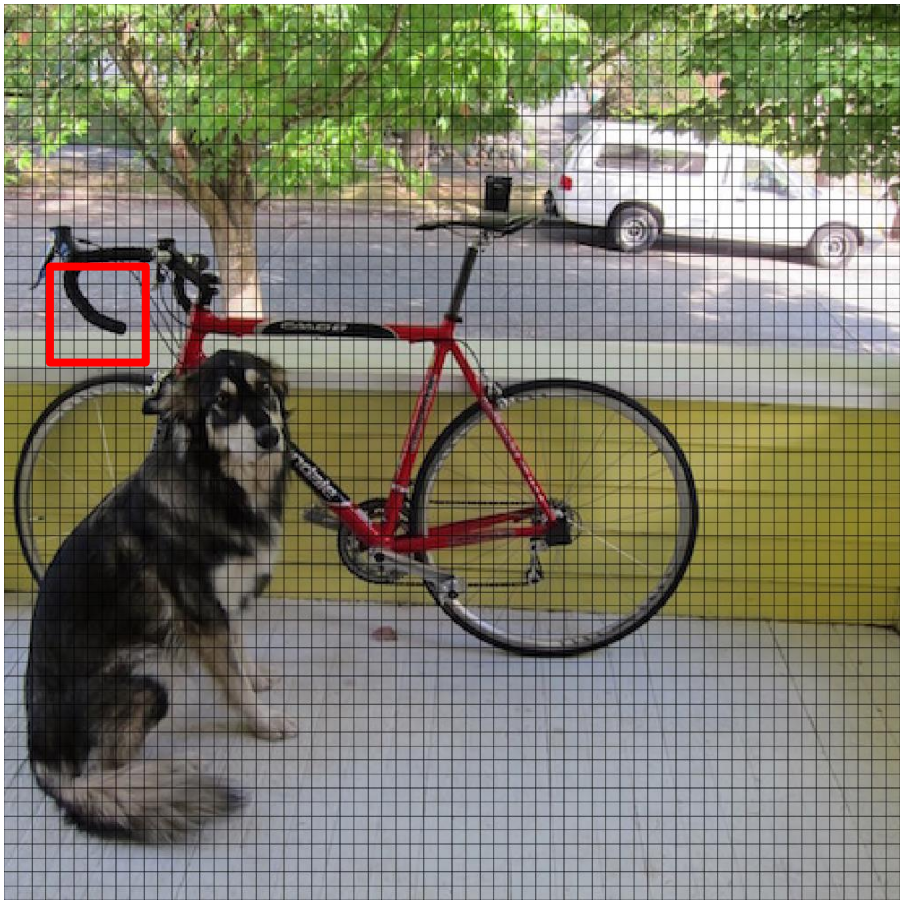
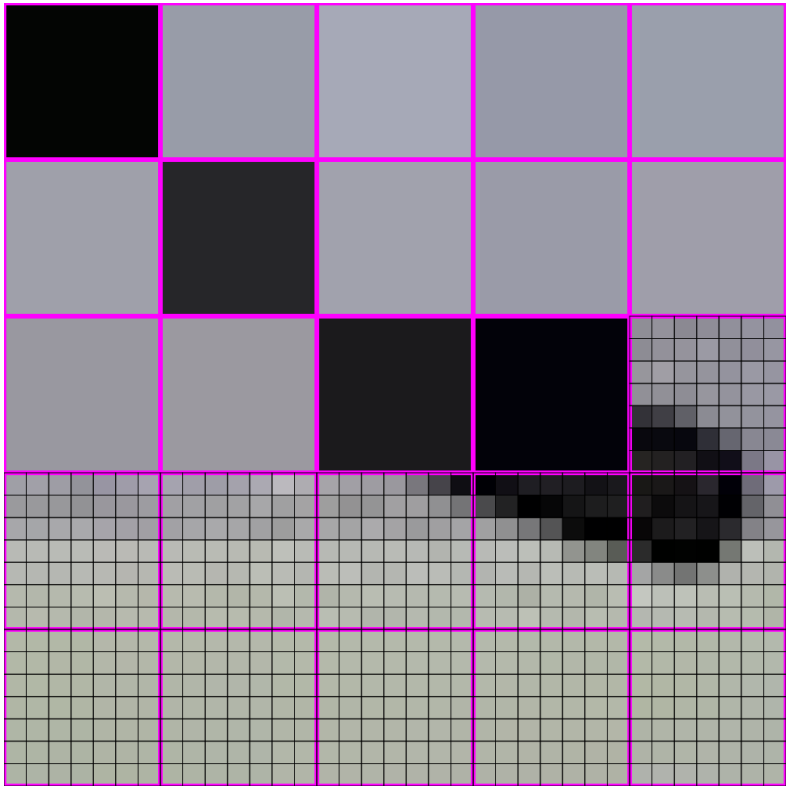
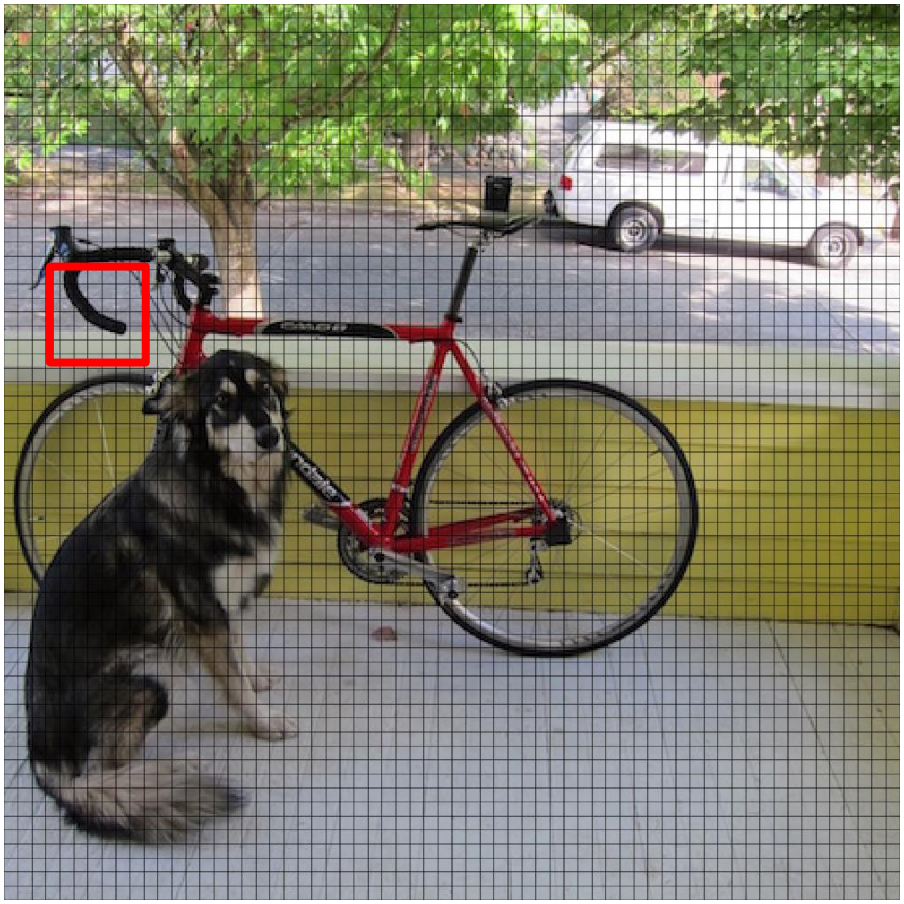
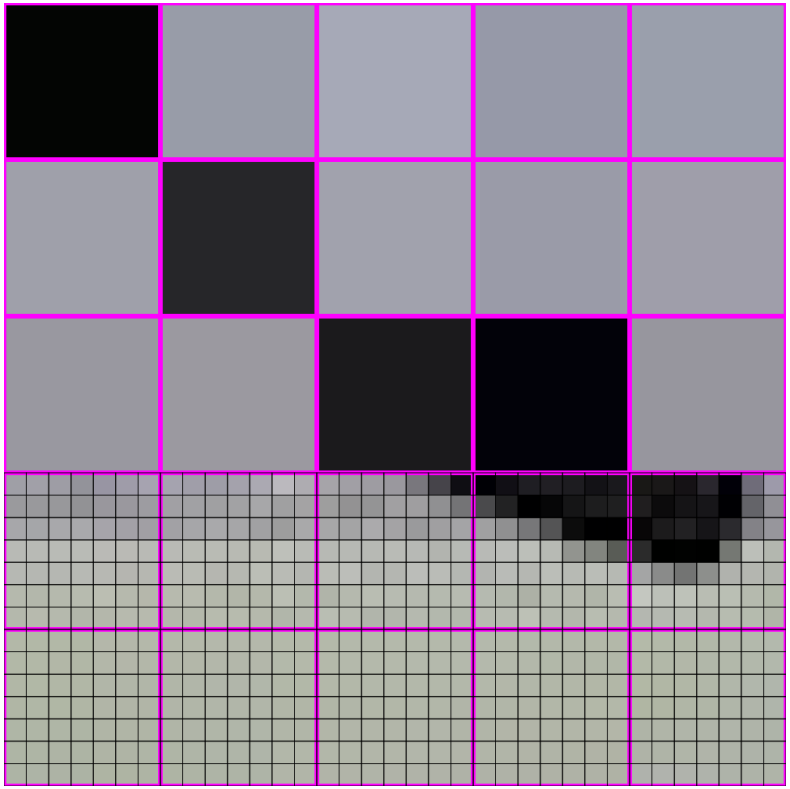


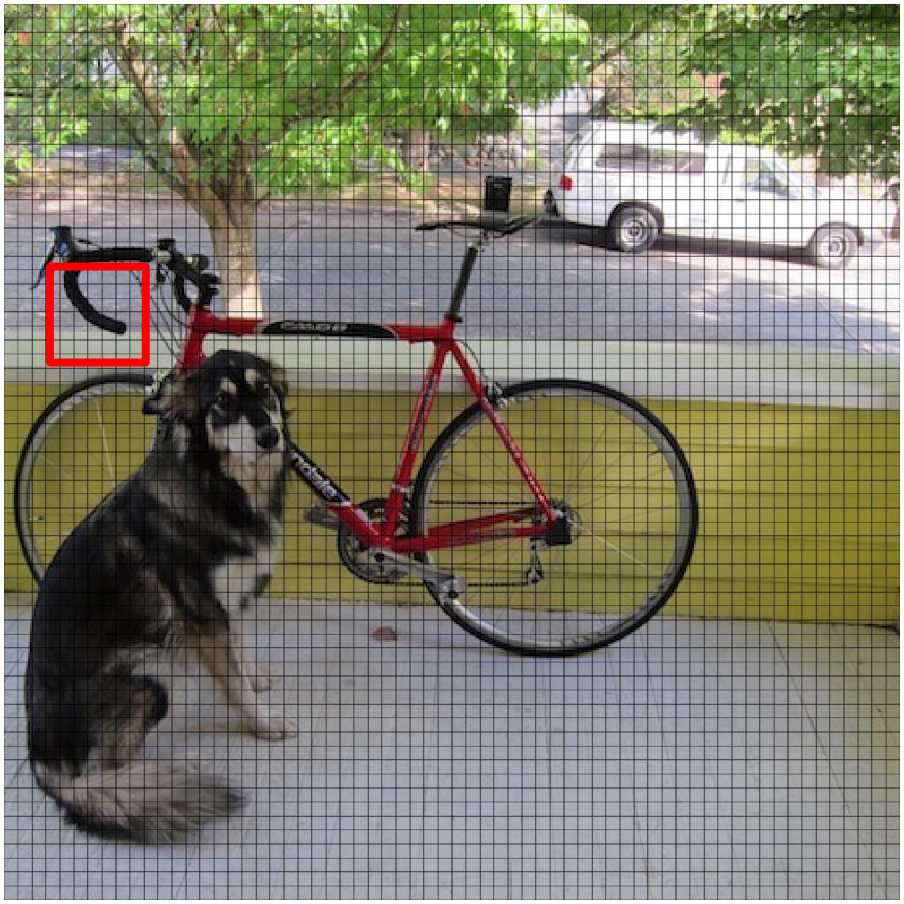


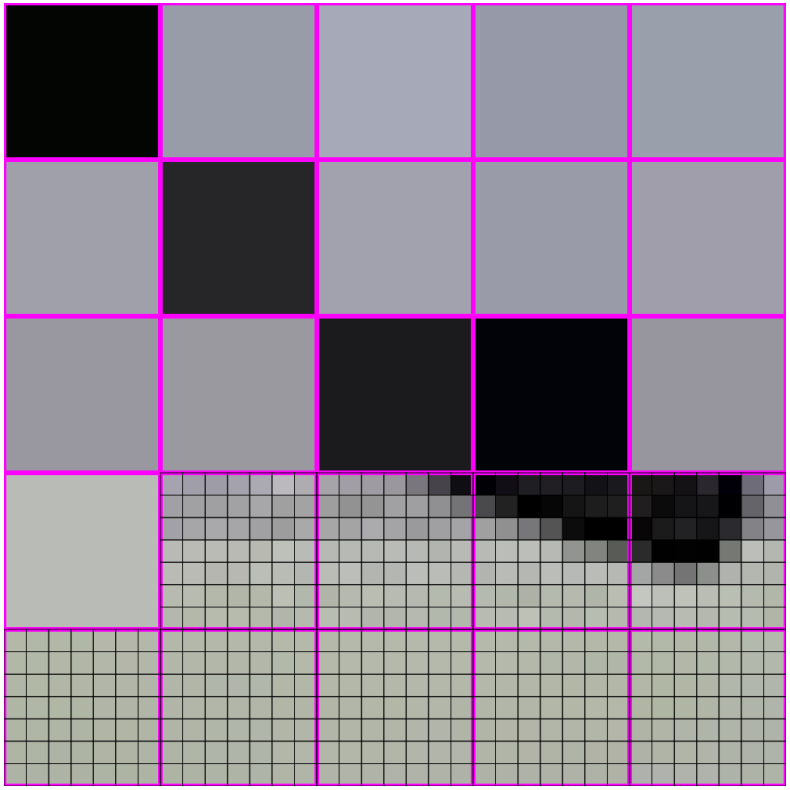
448x448 -> 64x64



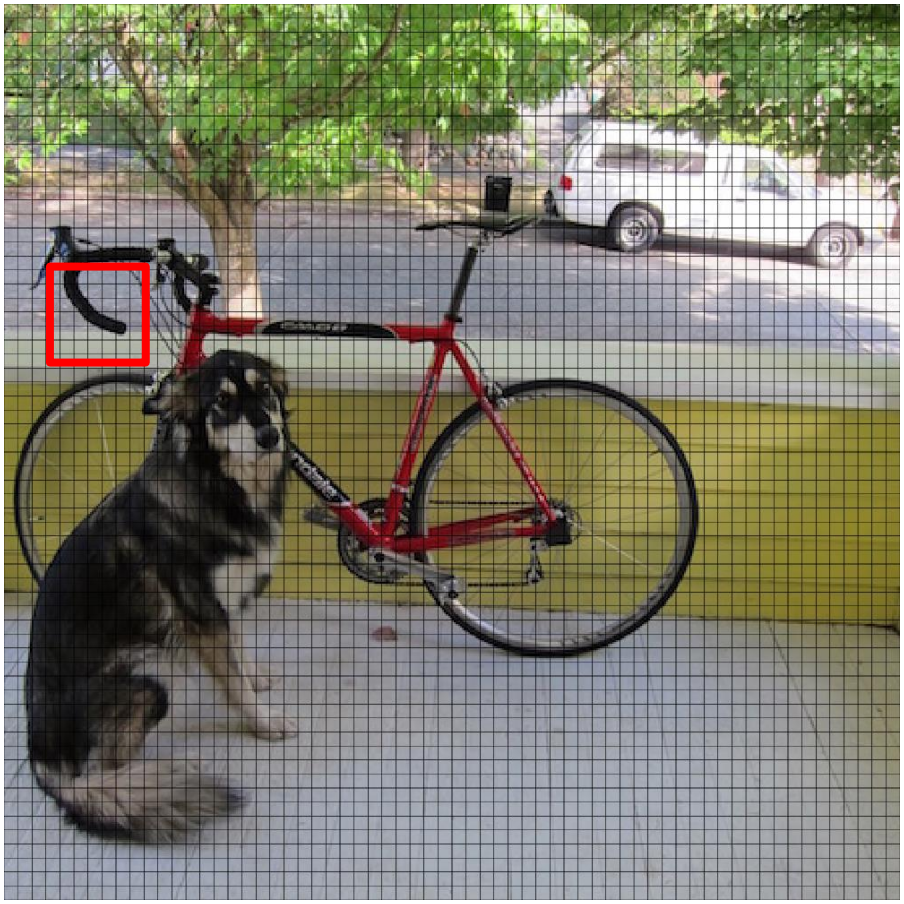


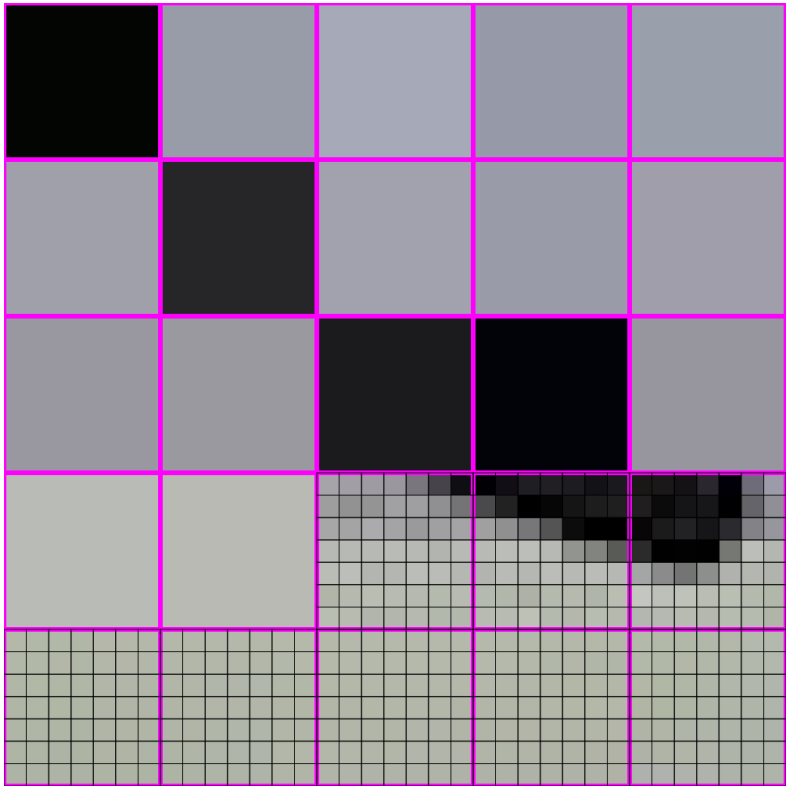
448x448 -> 64x64



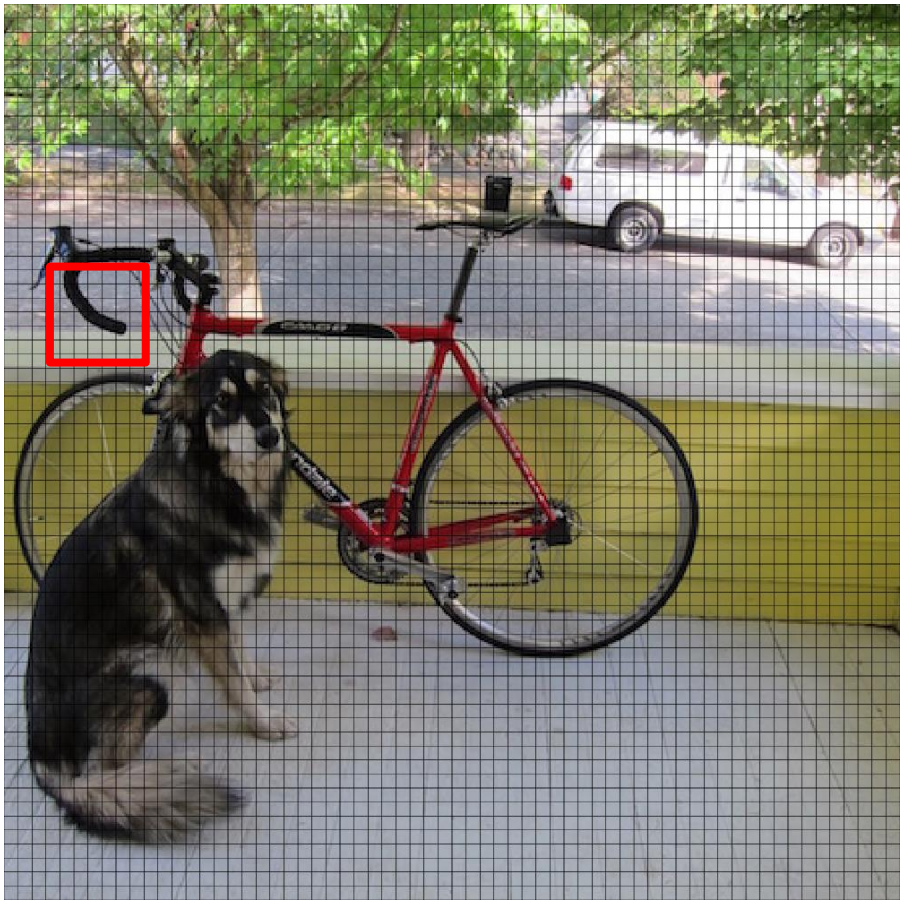


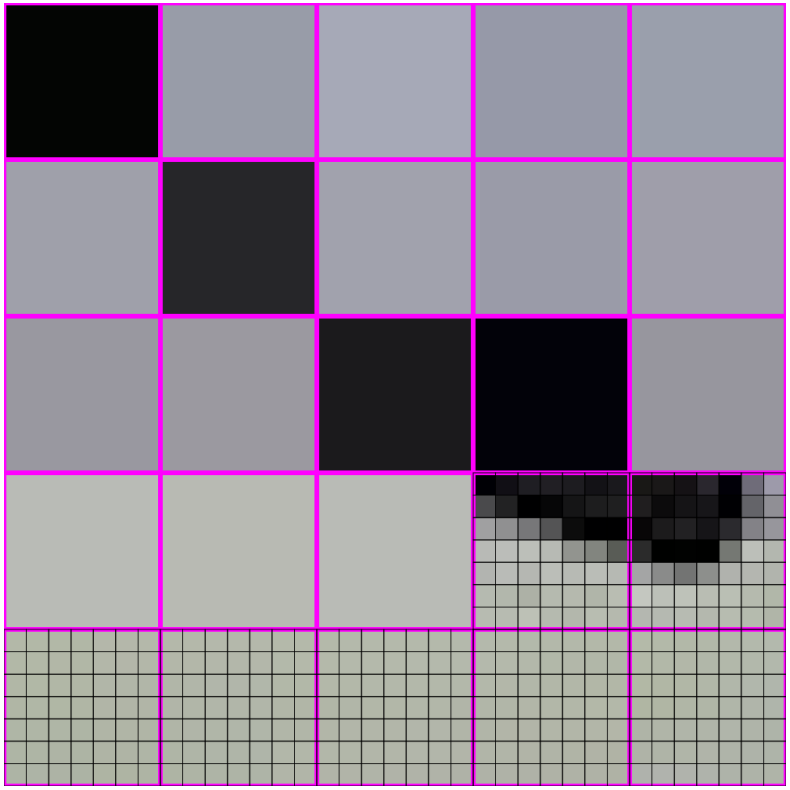
448x448 -> 64x64



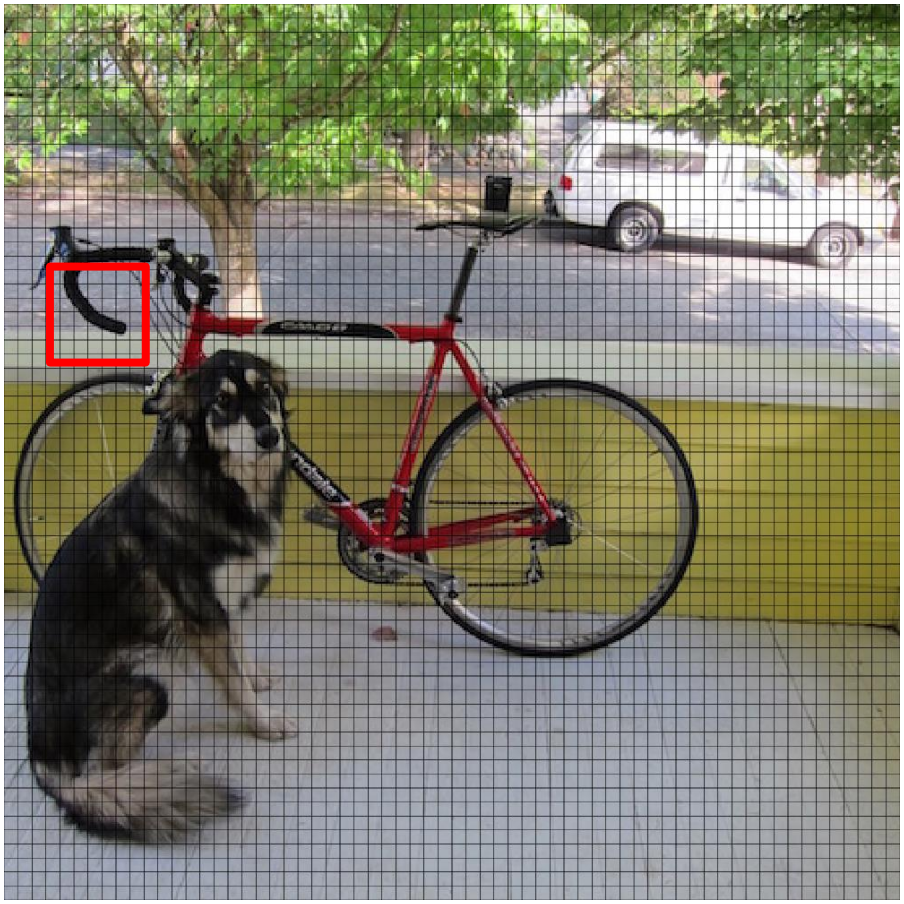


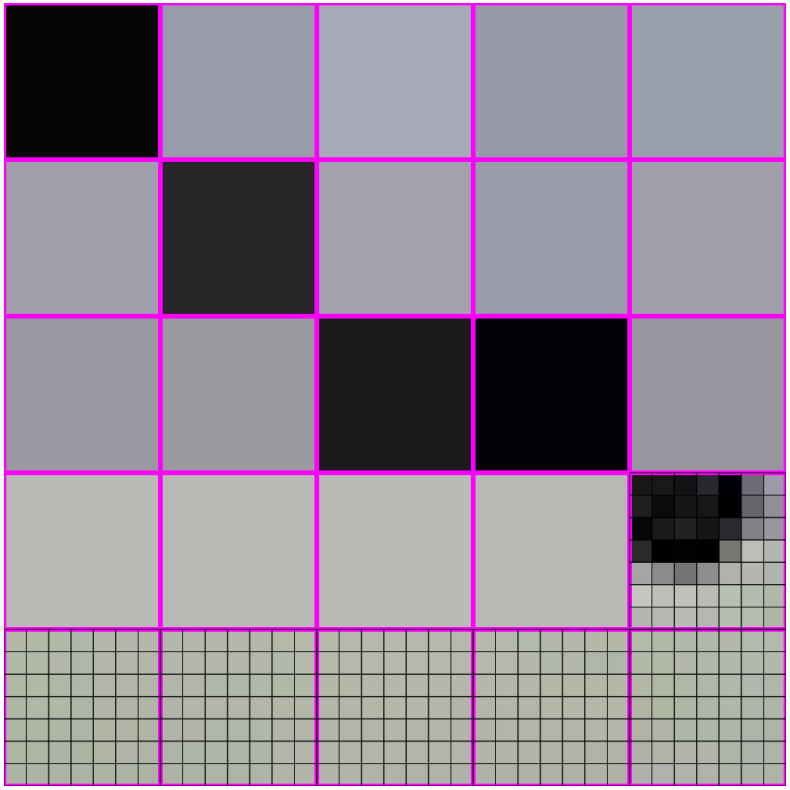
448x448 -> 64x64



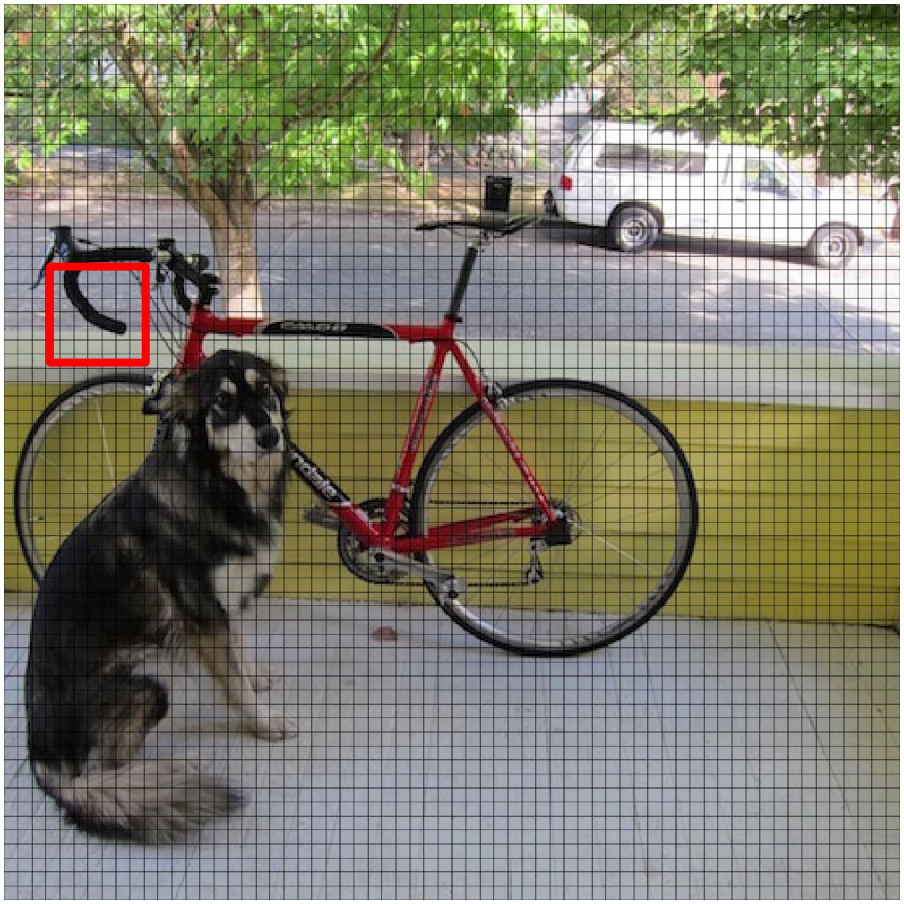


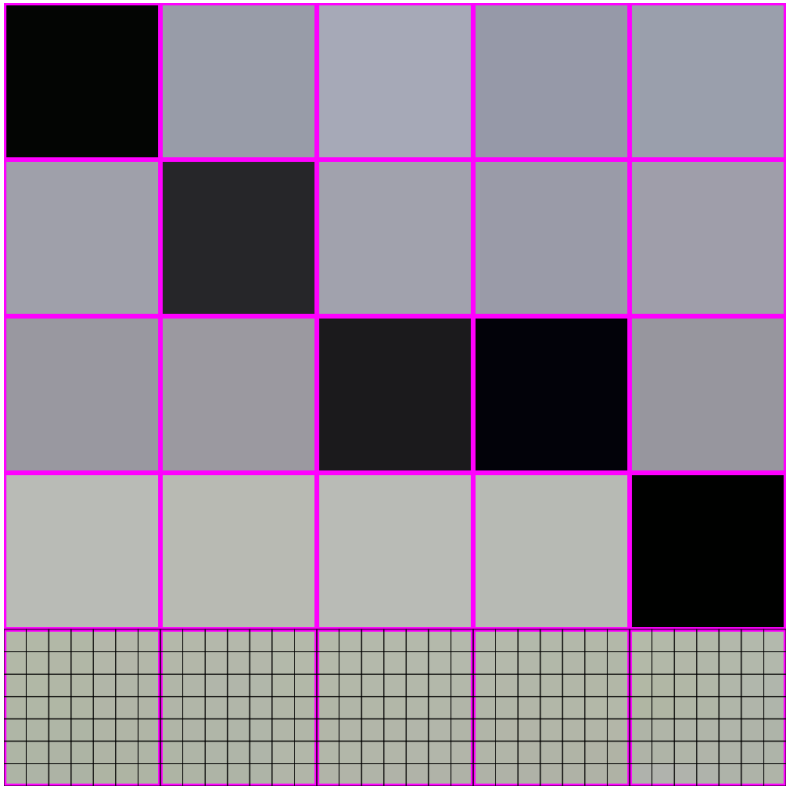
448x448 -> 64x64



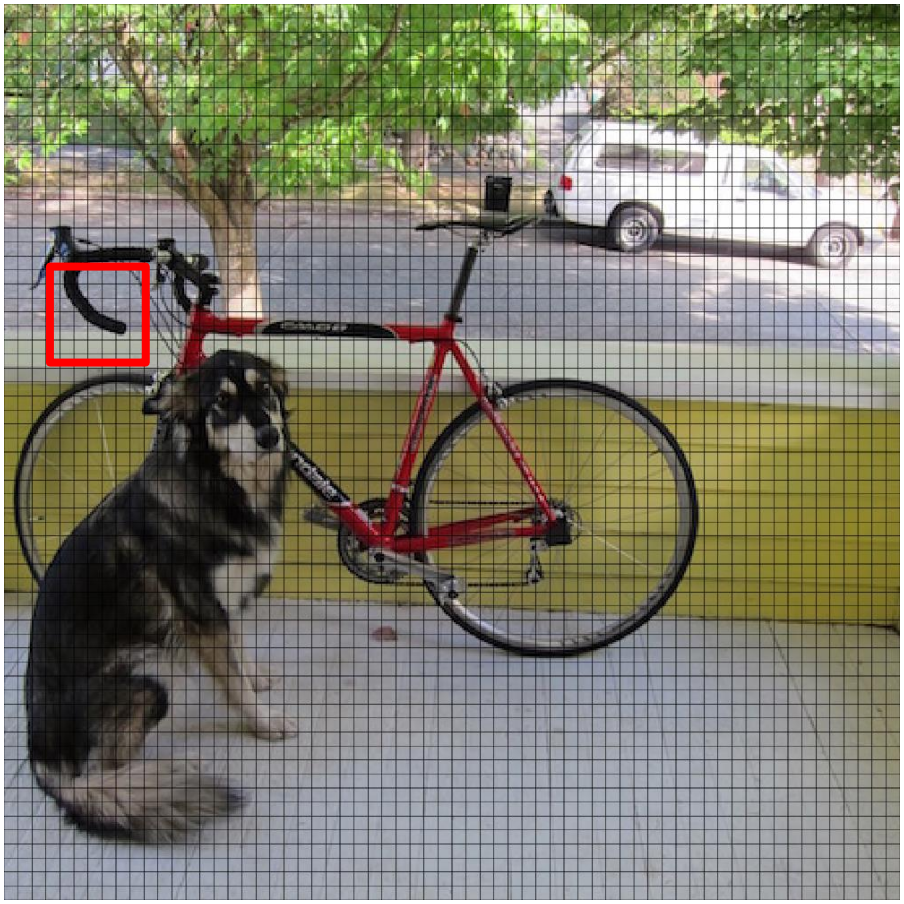


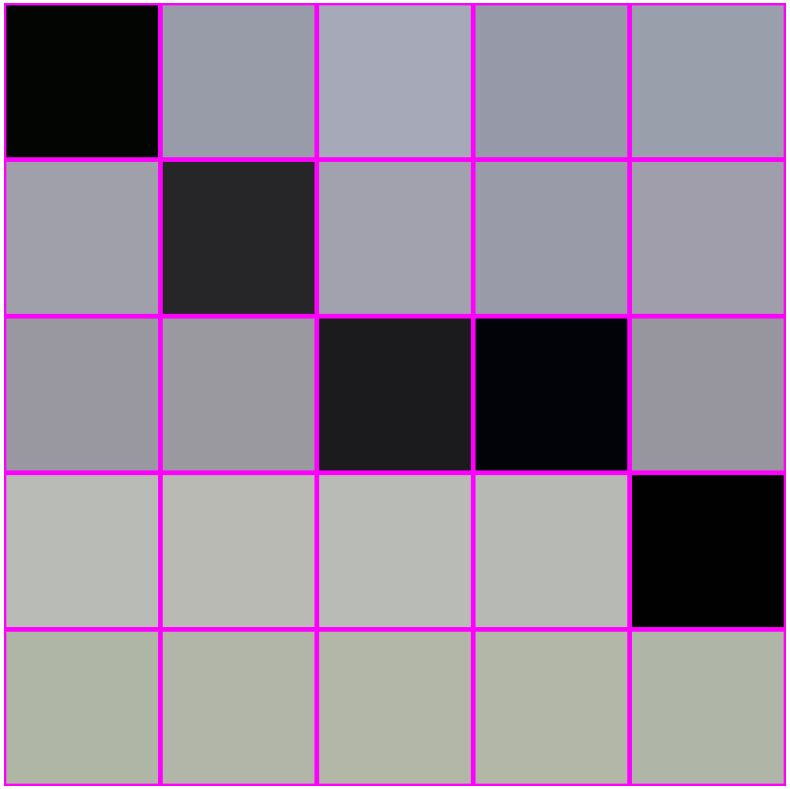
448x448 -> 64x64



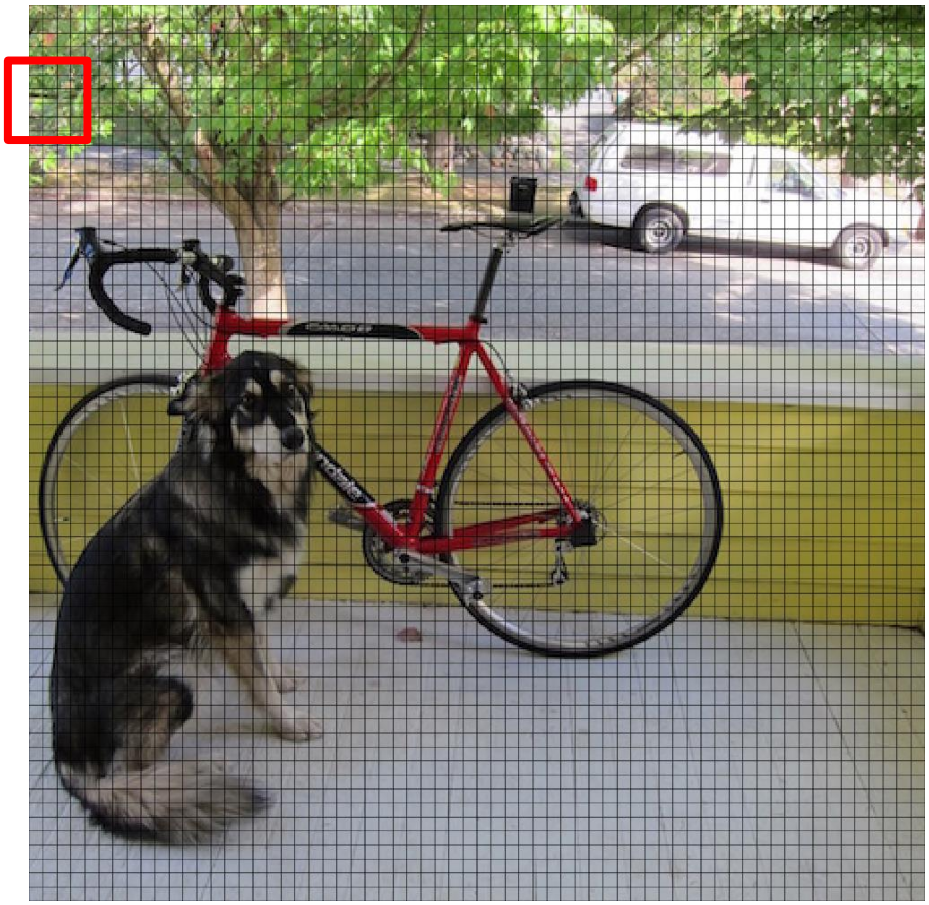


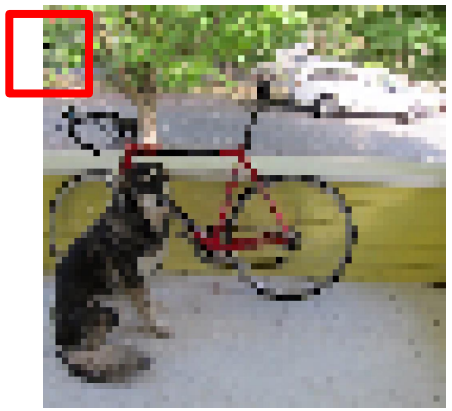
448x448 -> 64x64



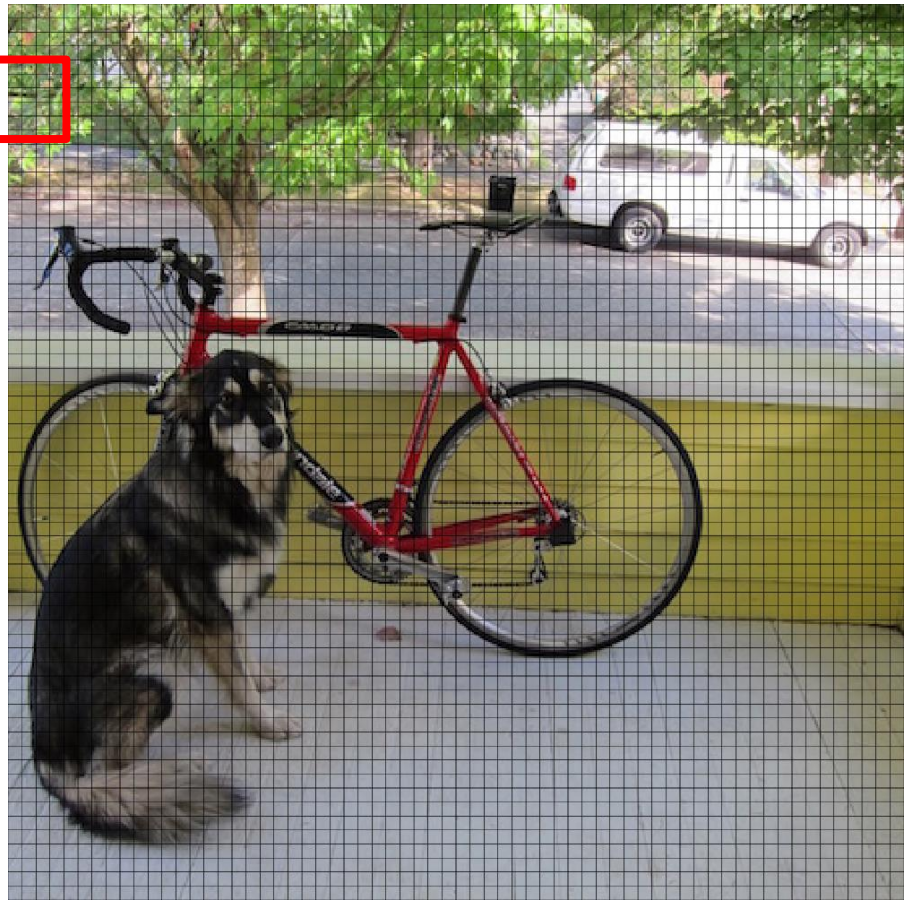


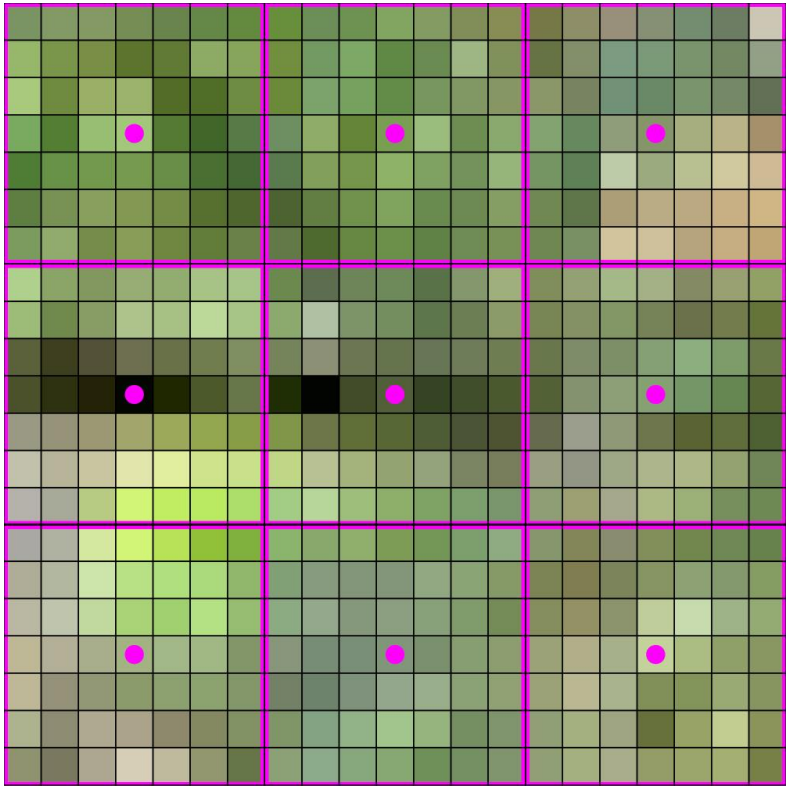
448x448 -> 64x64



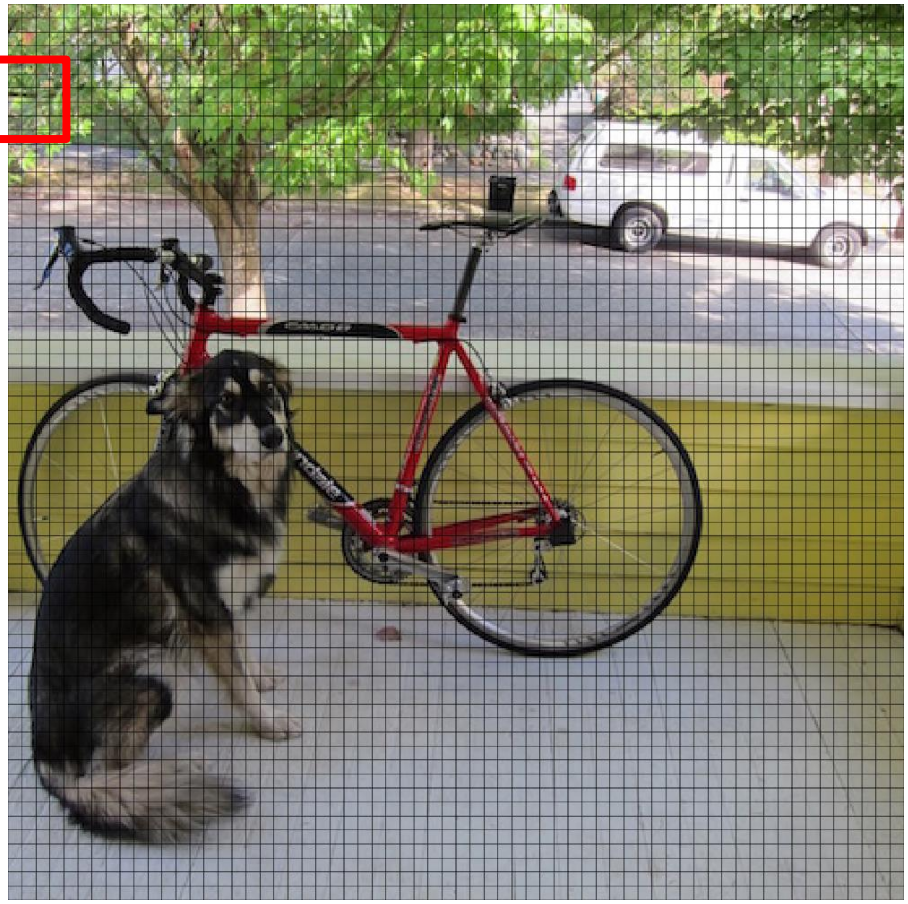


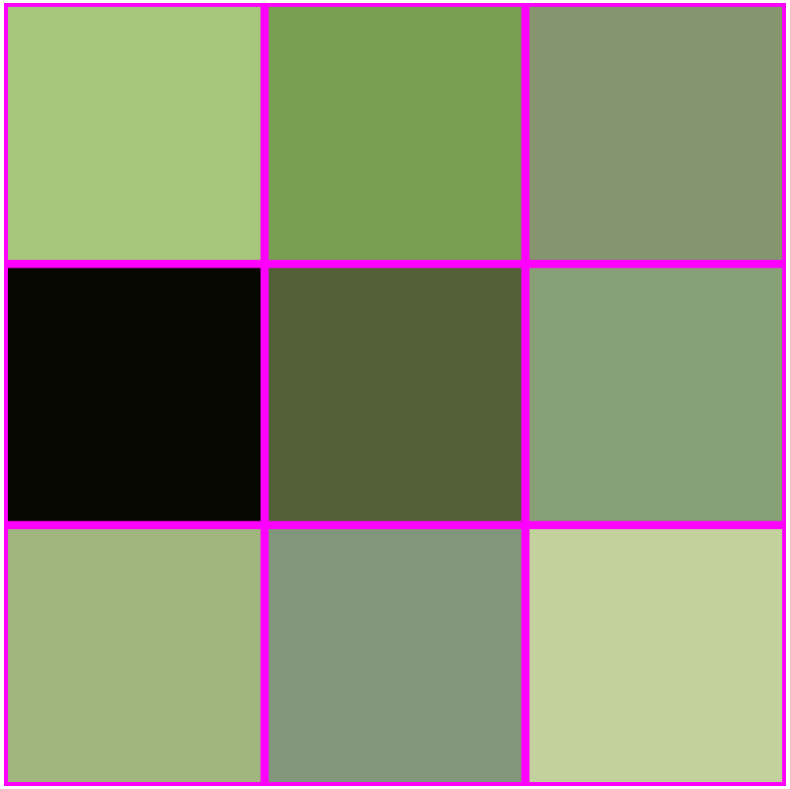
448x448 -> 64x64



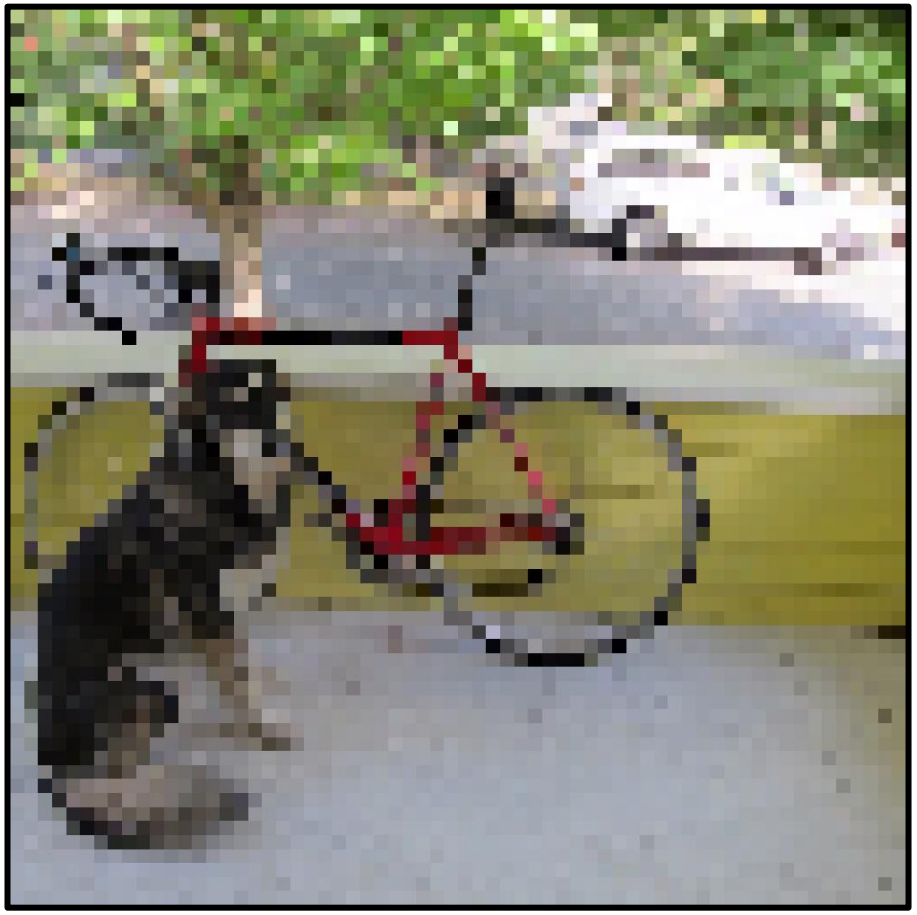


448x448 -> 64x64





IS THIS ALL THERE IS??

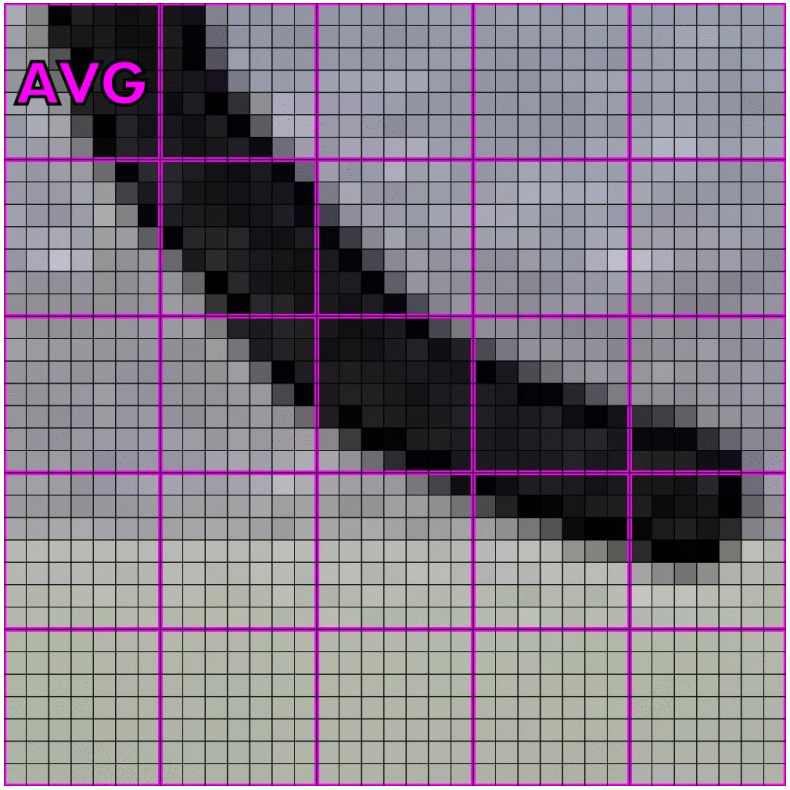


THERE IS A BETTER WAY!

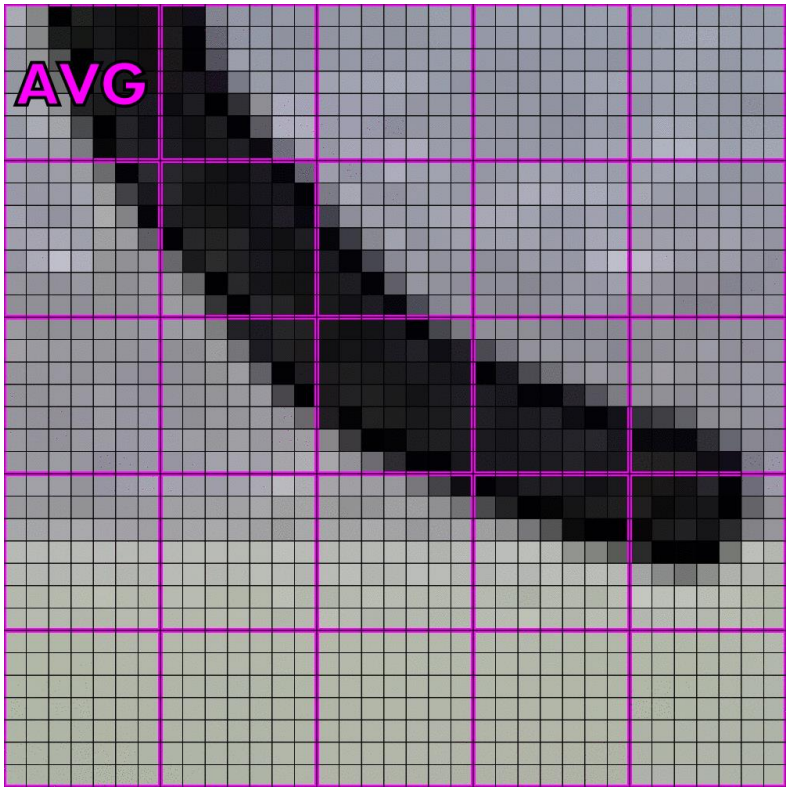
LOOK AT HOW MUCH BETTER

How do?

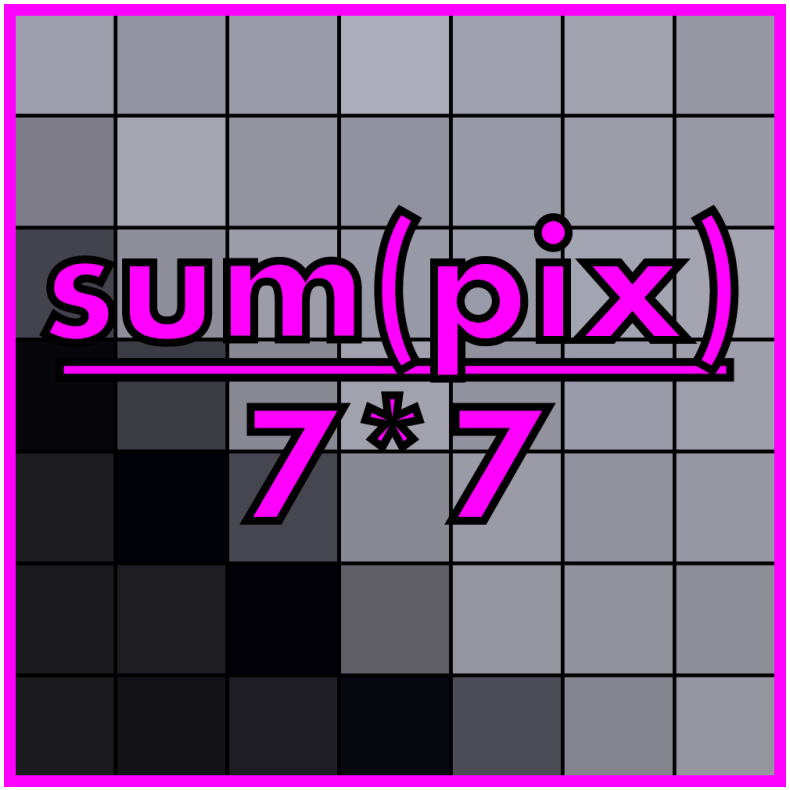
How do? Averaging!



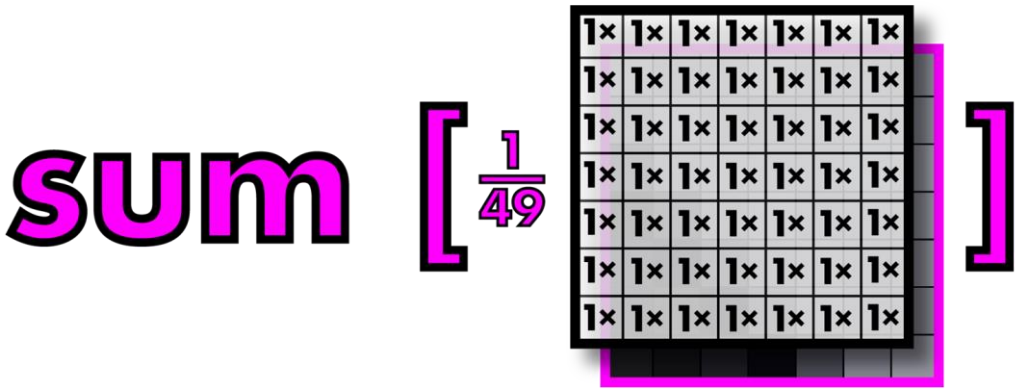
What is averaging?



What is averaging? A weighted sum

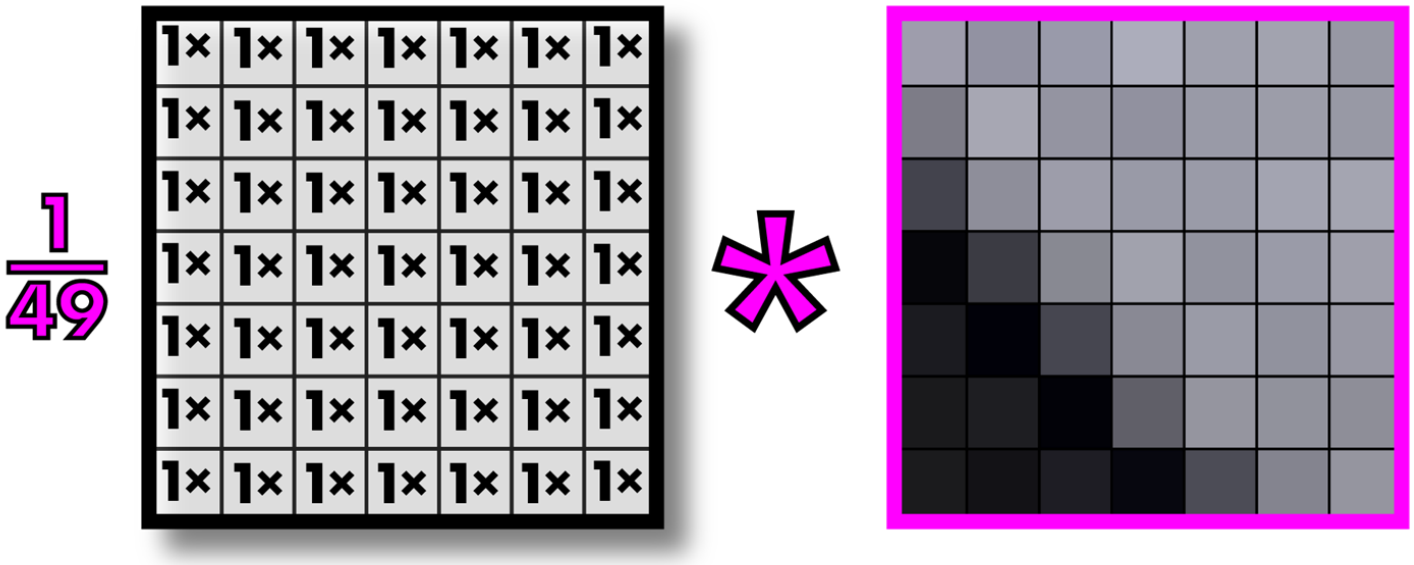


What is averaging? A weighted sum



Call this operation "*convolution*"

Filter or *kernel*



Note: multiplying an image section by a filter is actually called "correlation" and convolution Involves inverting the filter first, but since our filters are generally symmetric, we call Everything convolution. This is what all computer vision people do.

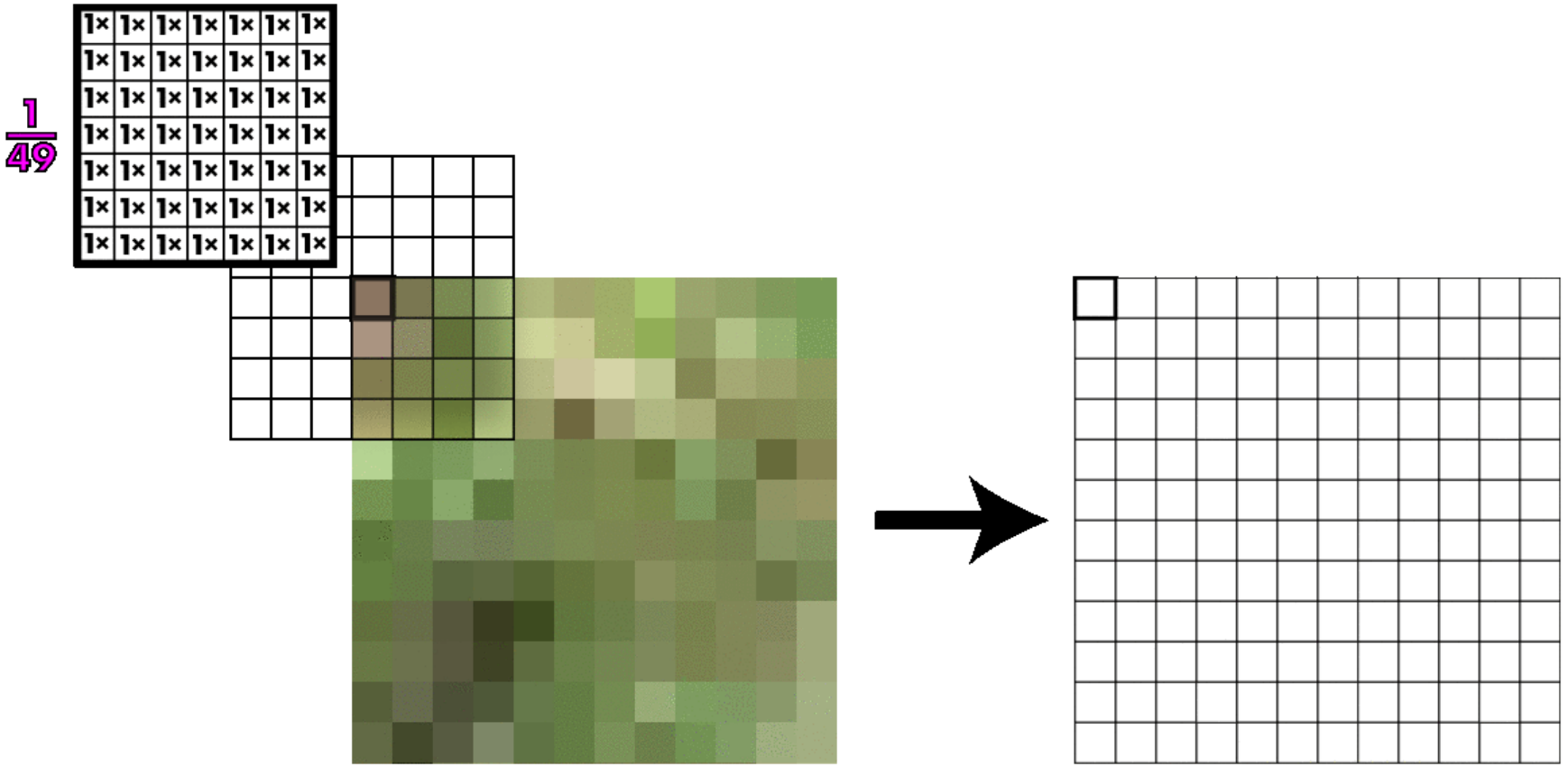
Convolutions on larger images

$$\frac{1}{49}$$

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×	1×	1×	1×
1×	1×	1×	1×	1×	1×	1×
1×	1×	1×	1×	1×	1×	1×
1×	1×	1×	1×	1×	1×	1×

$*$

Kernel slides across image



Kernel slides across image

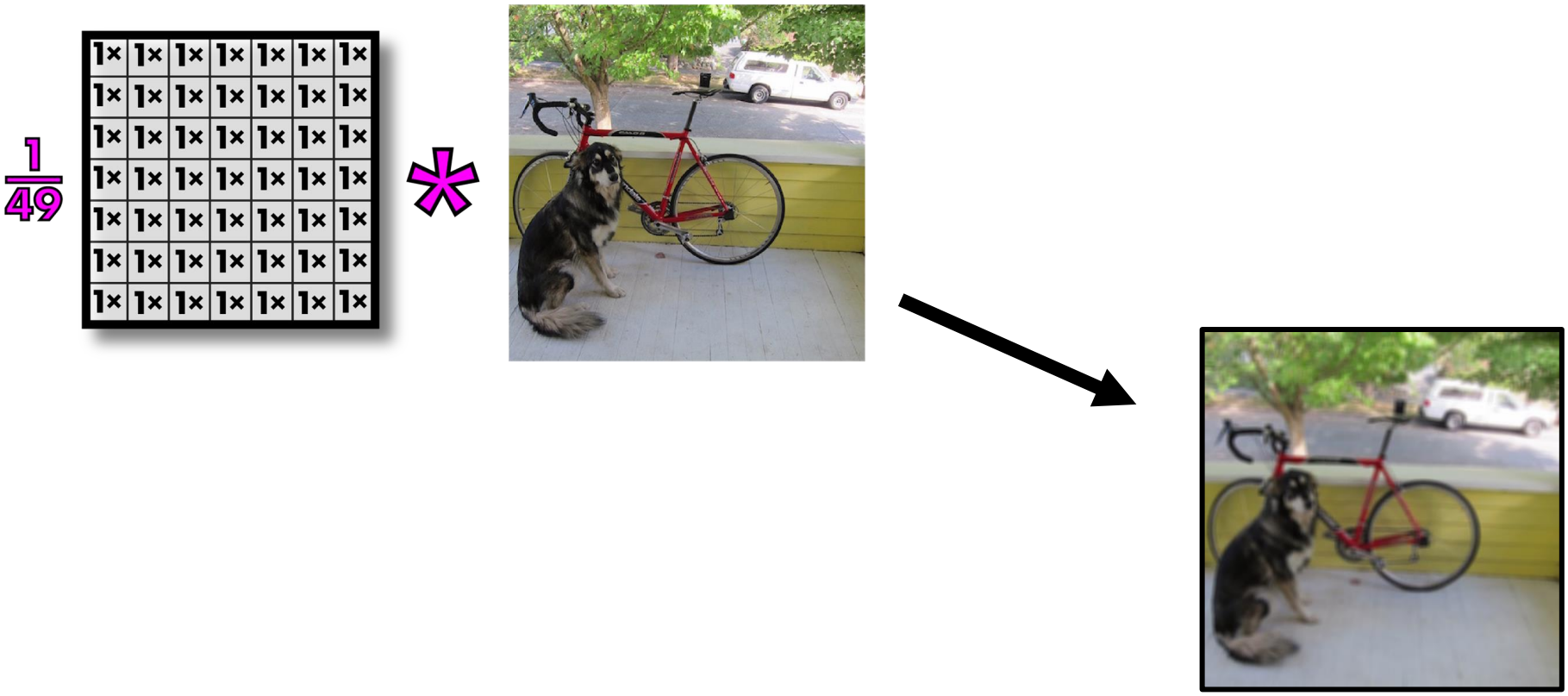
What happens at the edges of the images?

1. Zero padding: easiest but can give bad results

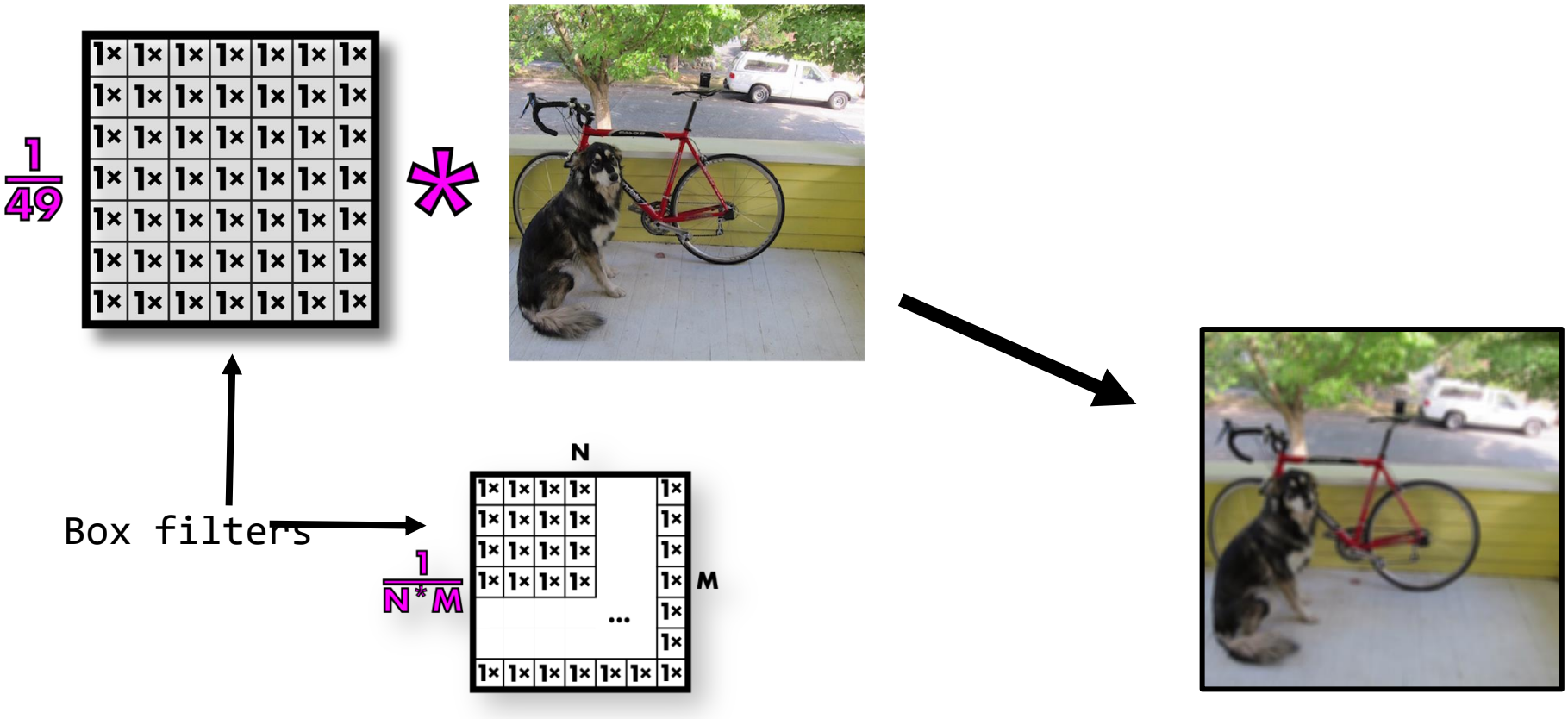
2. Duplicate the outermost row or column

3. Use wraparound

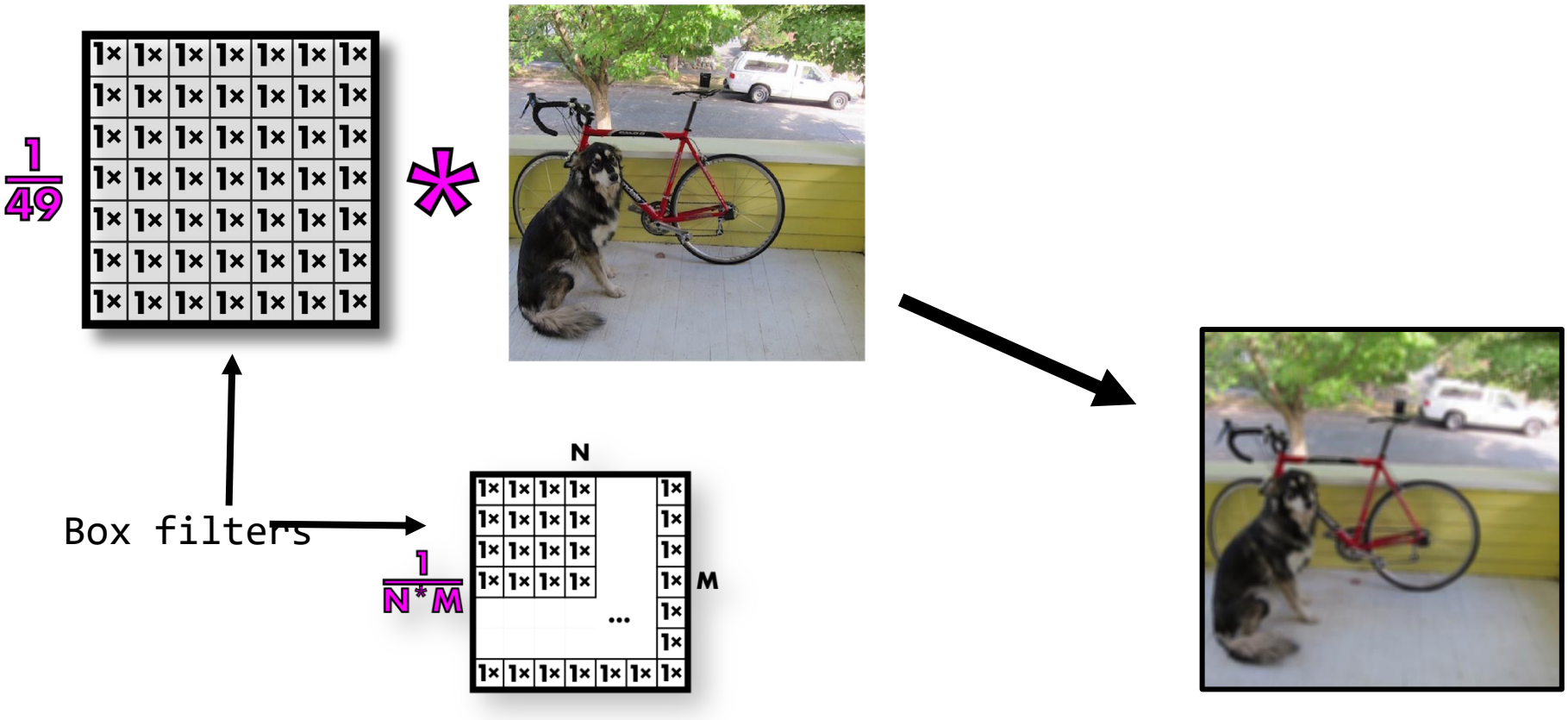
Convolutions on larger images



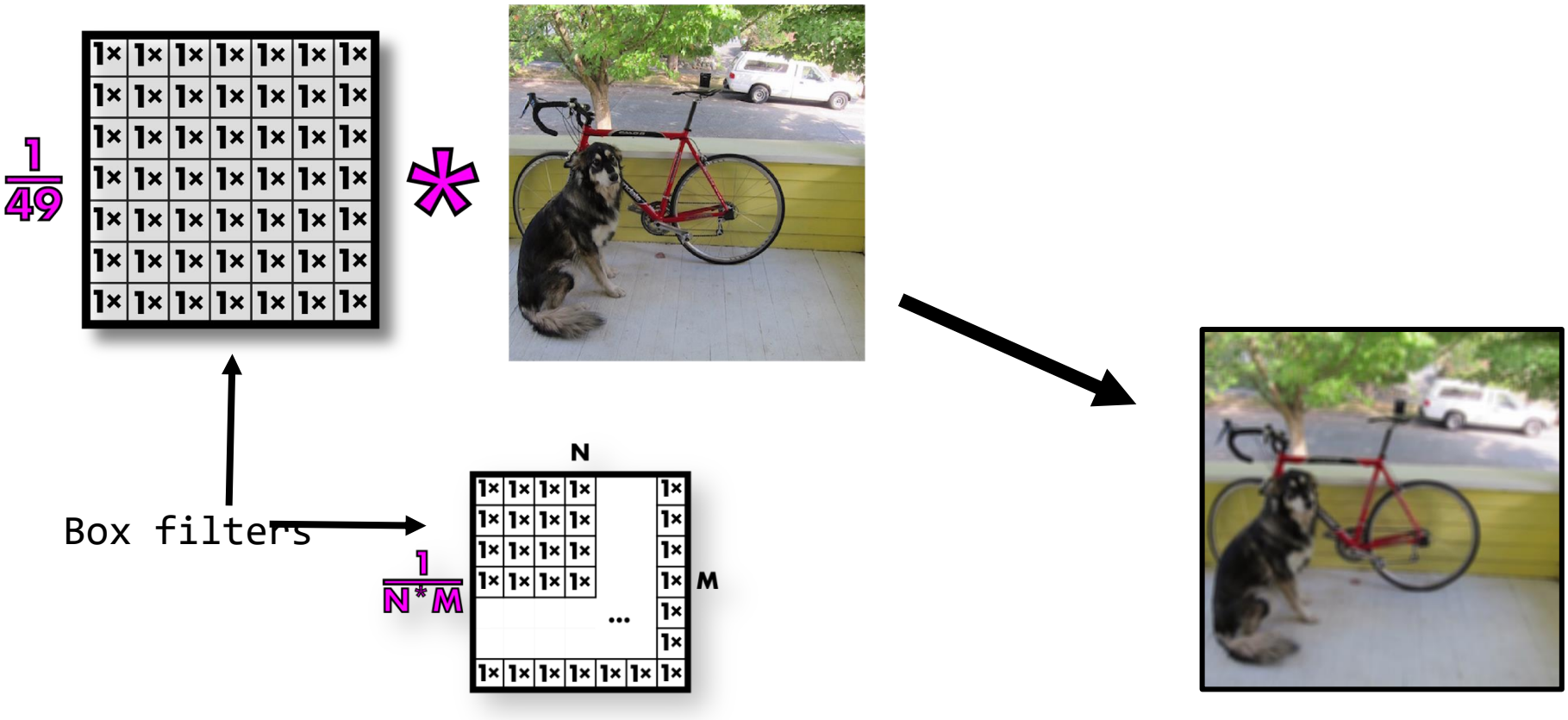
This is called box filter



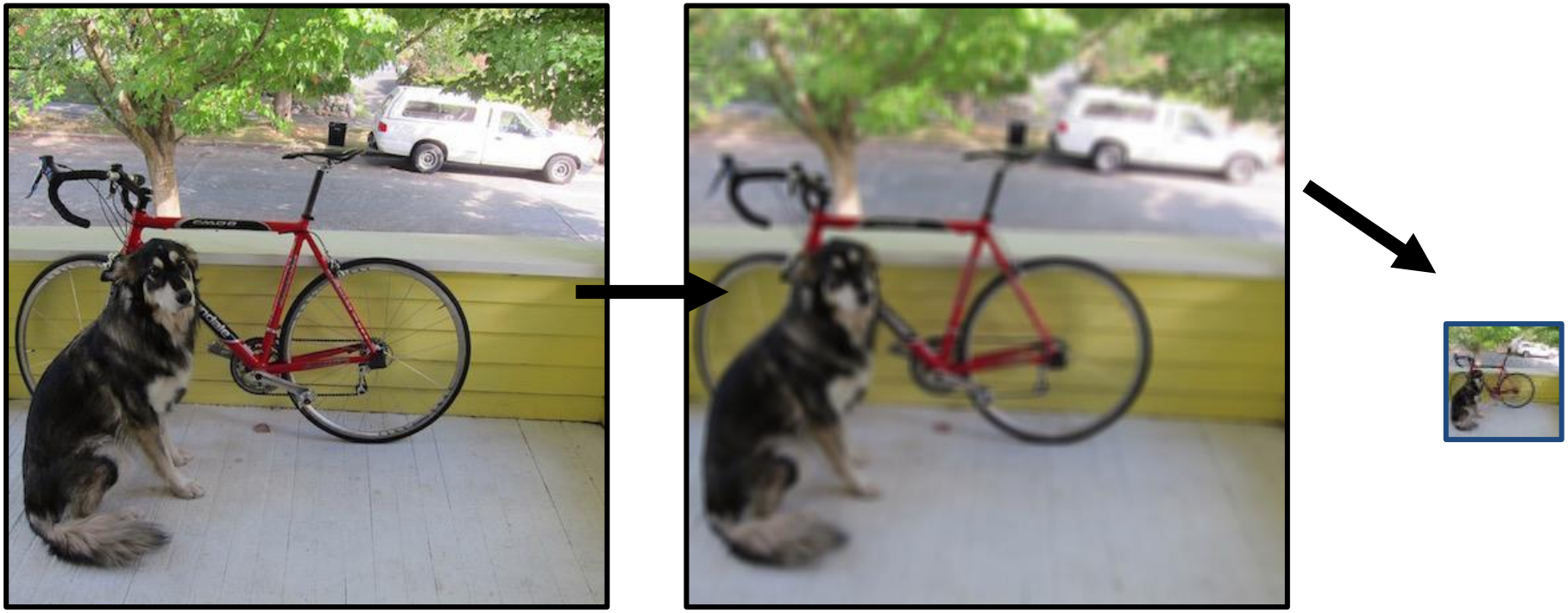
Box filters smooth image



Box filters smooth image

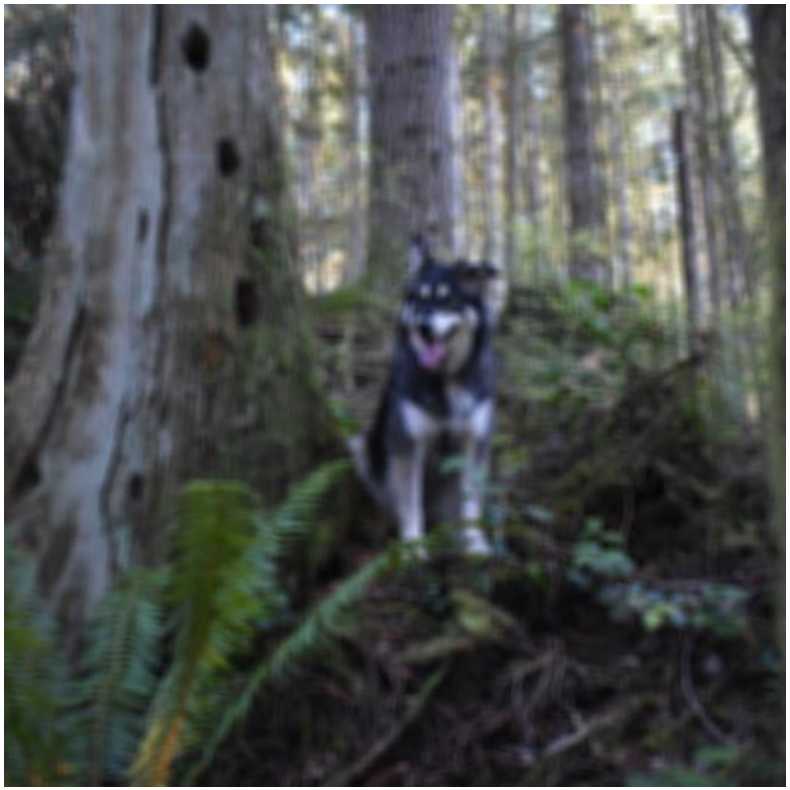


Now we resize our smoothed image



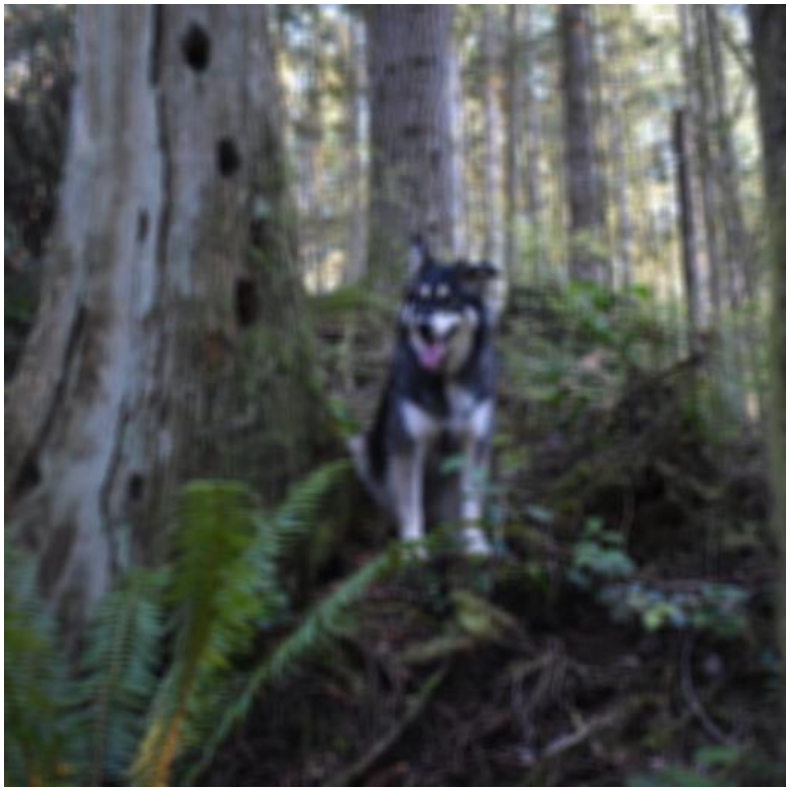
So much better!

Box filters have artifacts



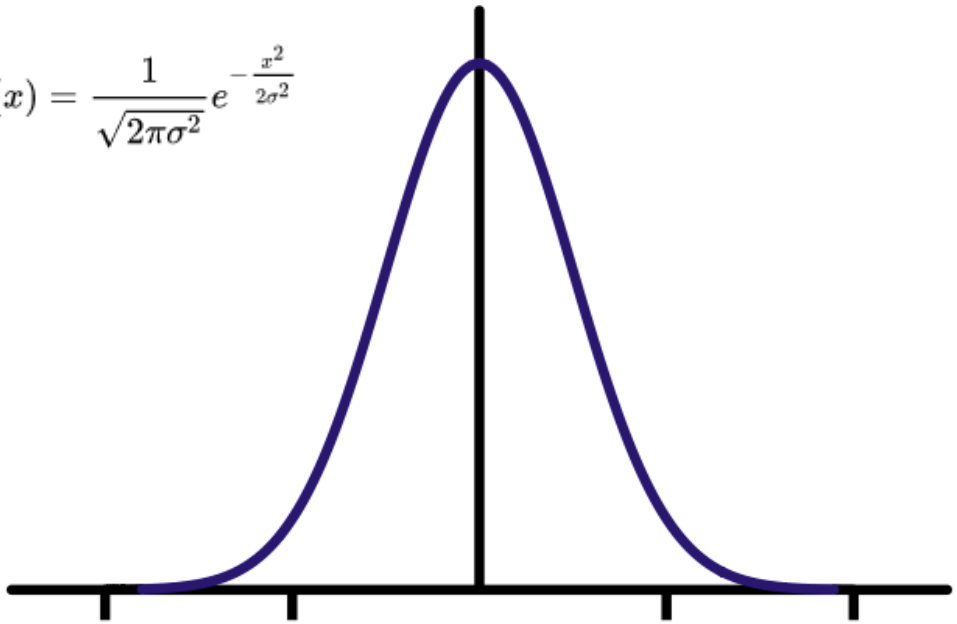
Box filters have artifacts

We want a smoothly weighted kernel



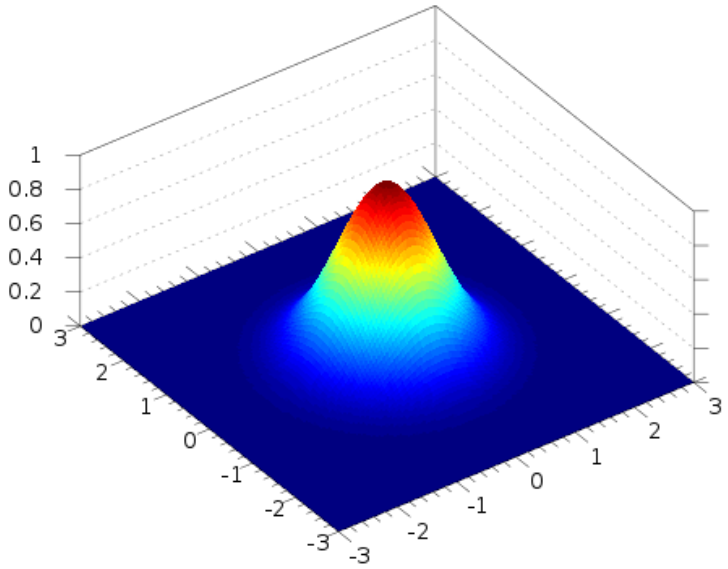
Gaussians

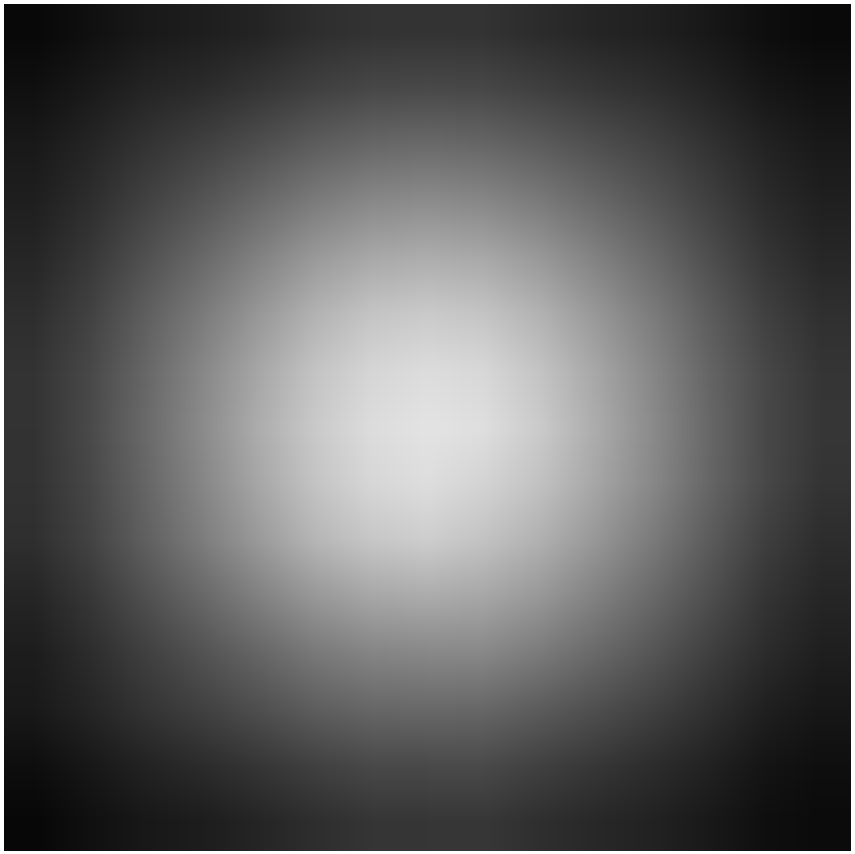
$$G(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{x^2}{2\sigma^2}}$$



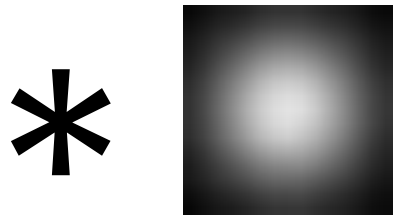
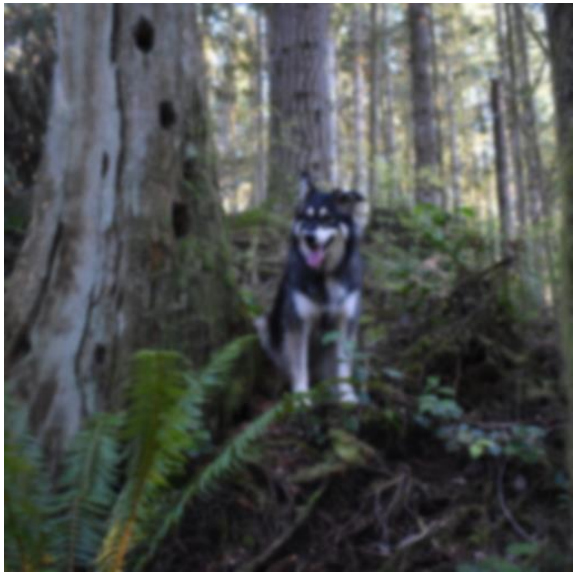
2d Gaussian

$$g(x,y) = \frac{1}{2\pi\sigma^2} \cdot e^{-\frac{x^2+y^2}{2\sigma^2}}$$

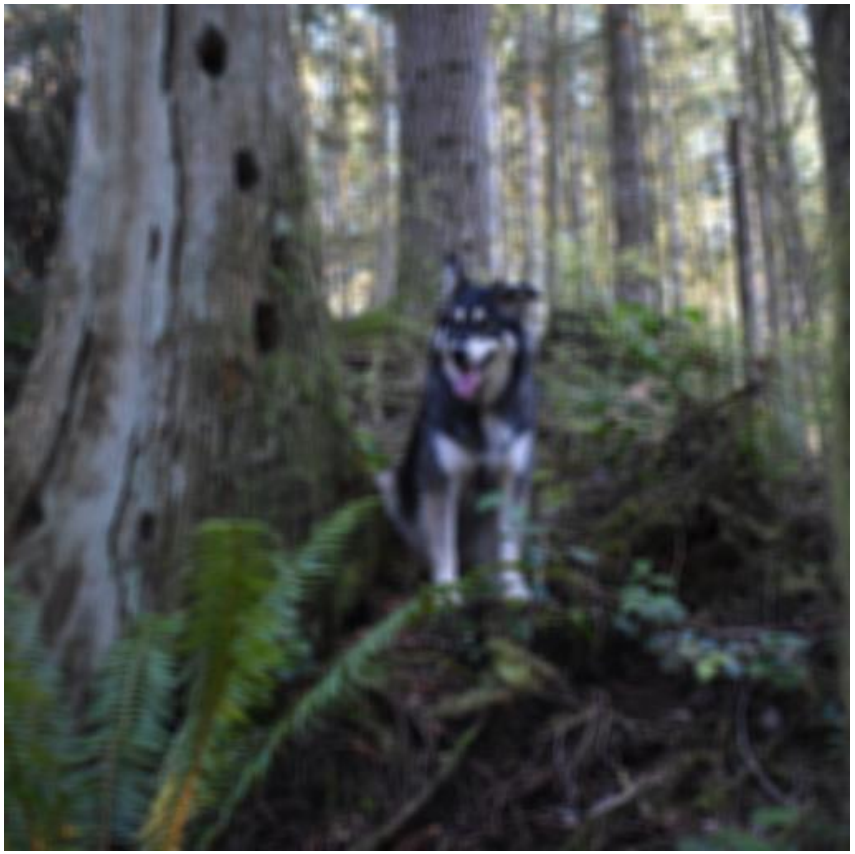


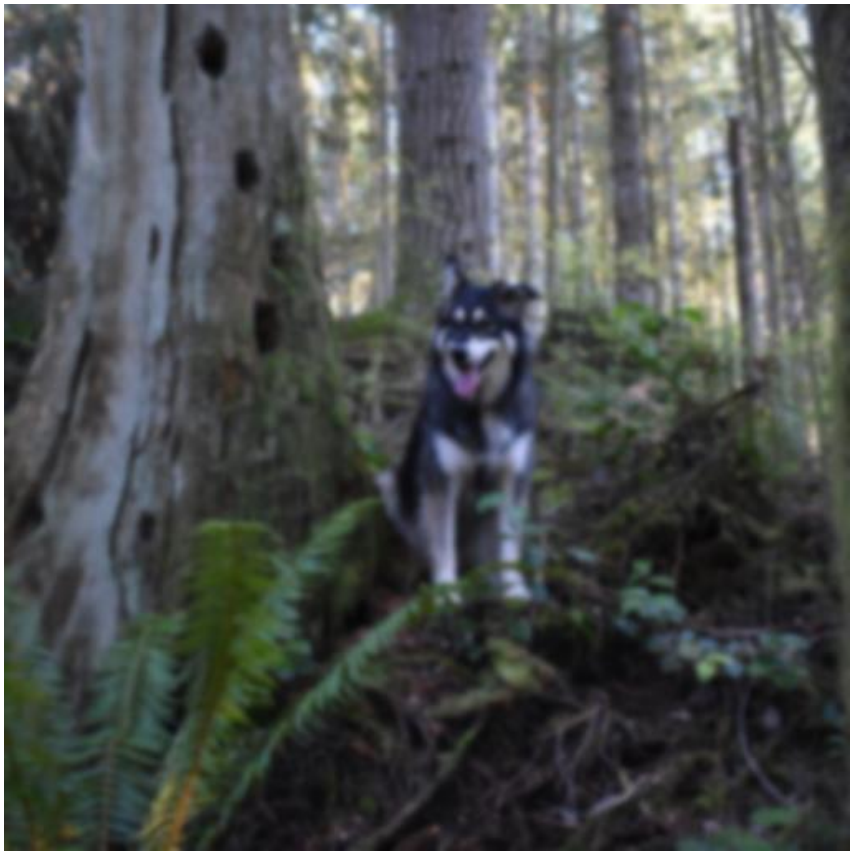


Better smoothing with Gaussians

Better smoothing with Gaussians



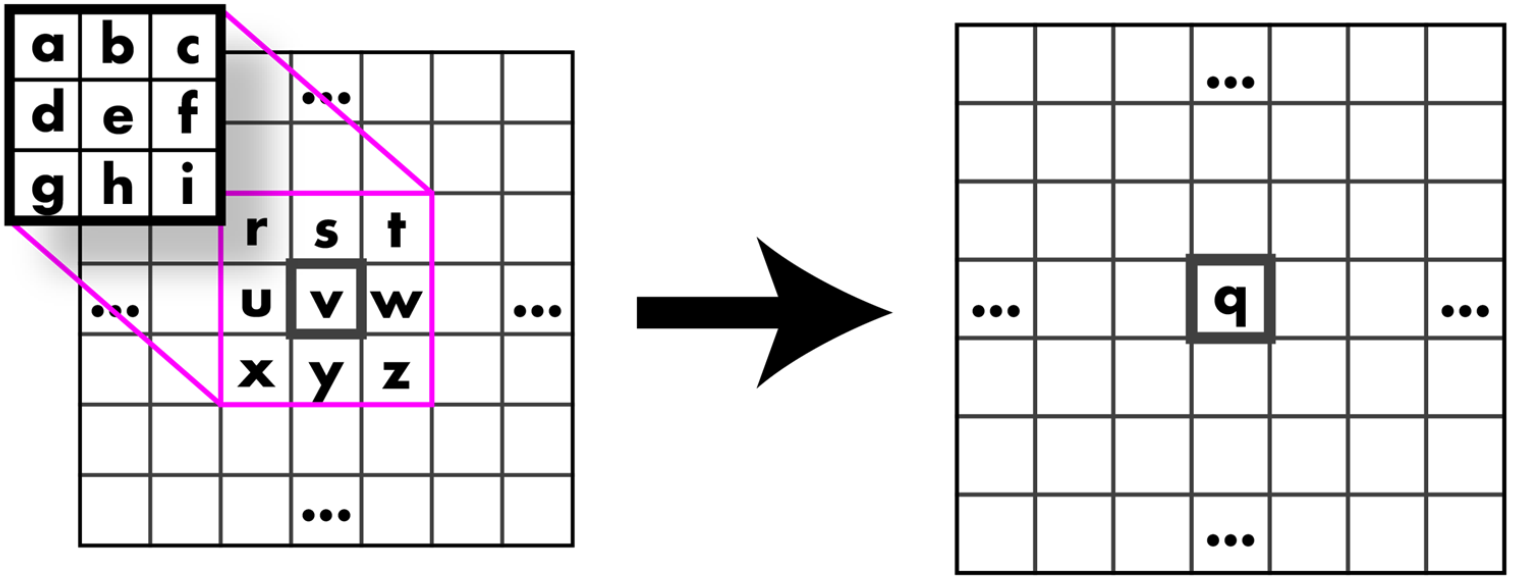


Better smoothing with Gaussians

Box Filtered

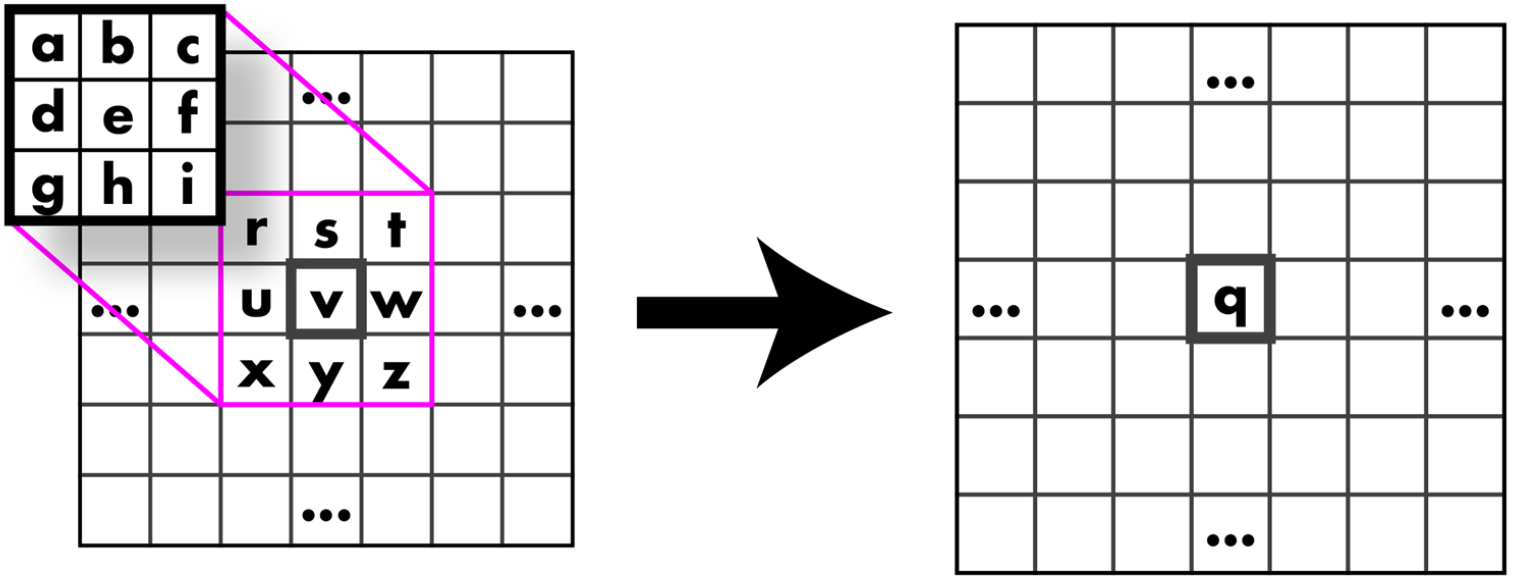
Gaussian Filtered

Wow, so what was that convolution thing??



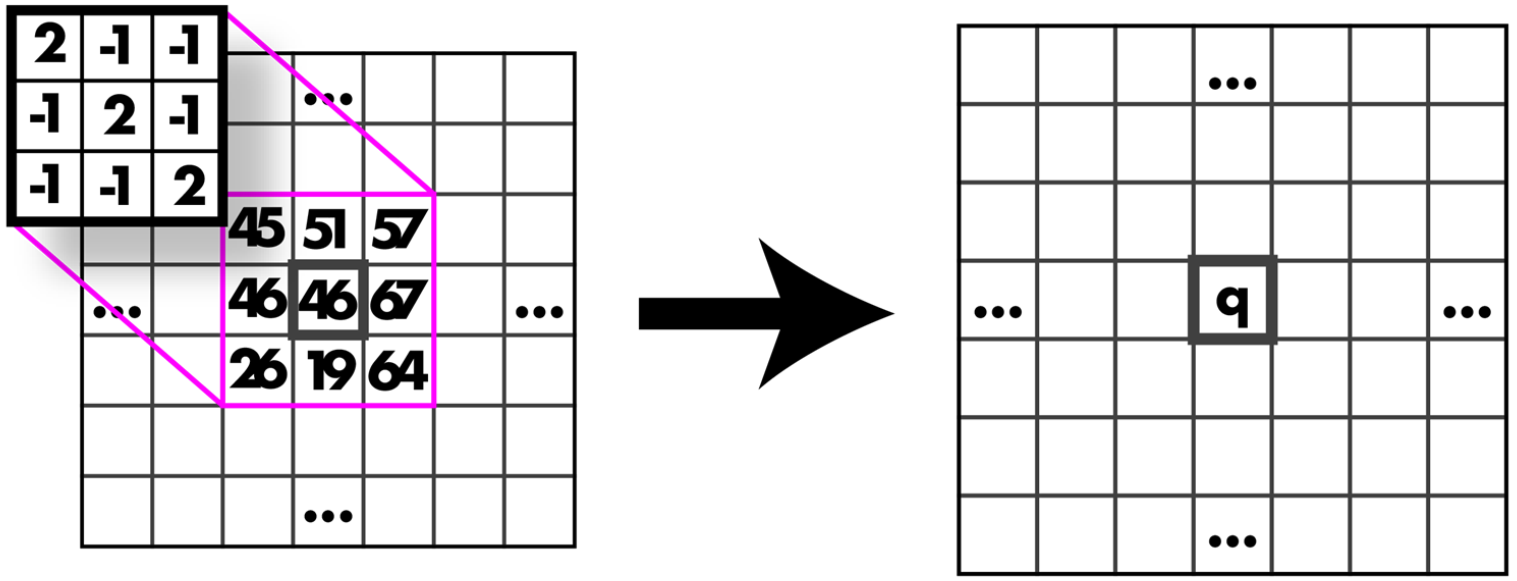
$$q = a \times r + b \times s + c \times t + d \times u + e \times v + f \times w + g \times x + h \times y + i \times z$$

Wow, so what was that convolution thing??

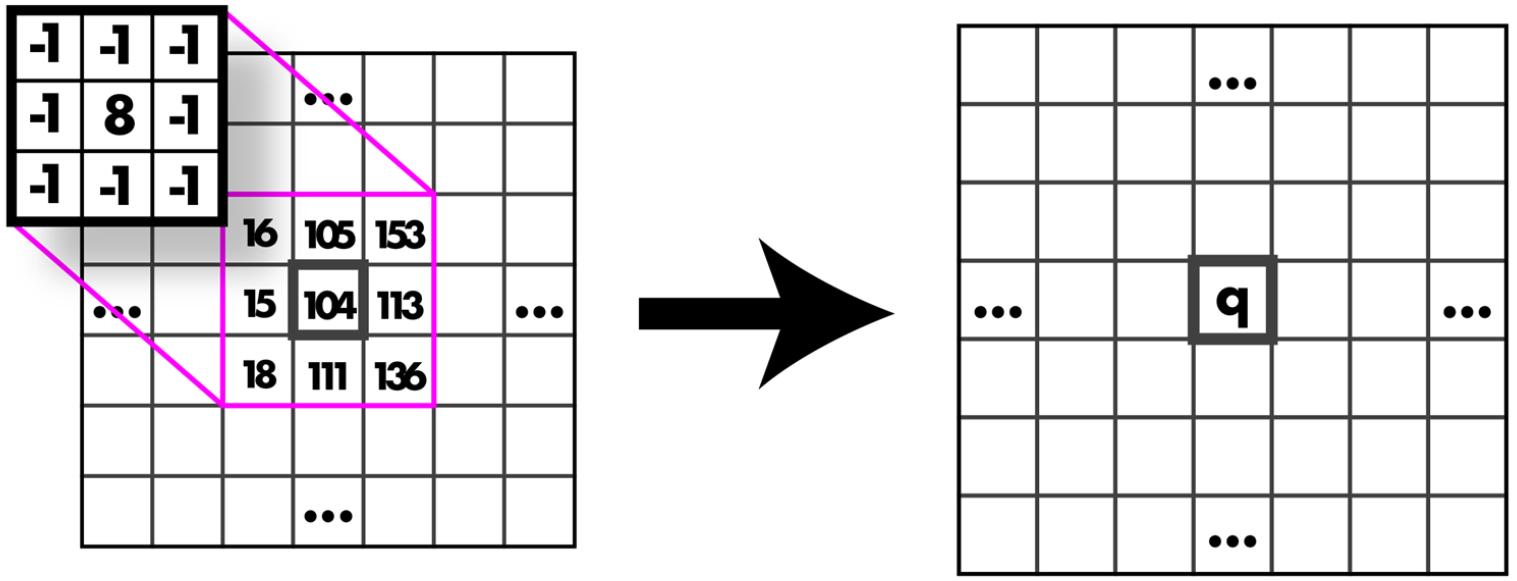


$$q = a \times r + b \times s + c \times t + d \times u + e \times v + f \times w + g \times x + h \times y + i \times z$$

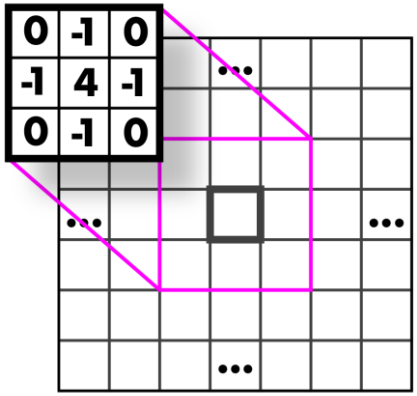
Calculate it, go!



Calculate it, go!

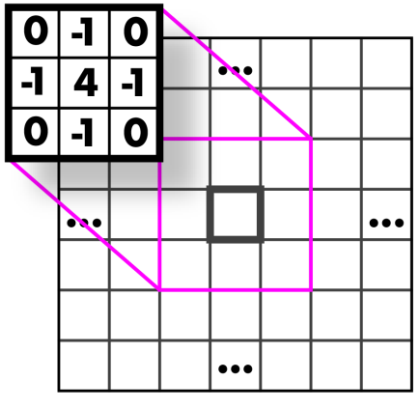


Guess that kernel!

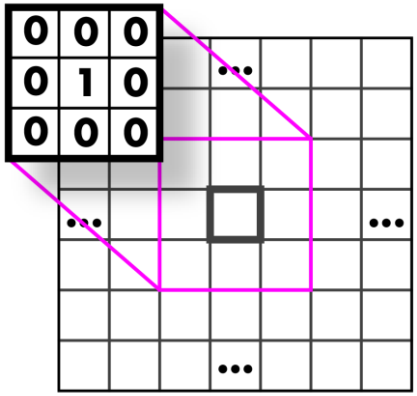


Highpass Kernel: finds edges

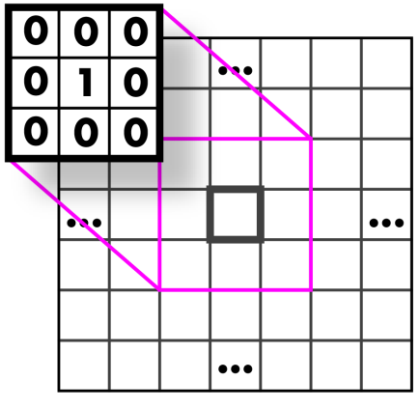
(applied to the graytone image!)



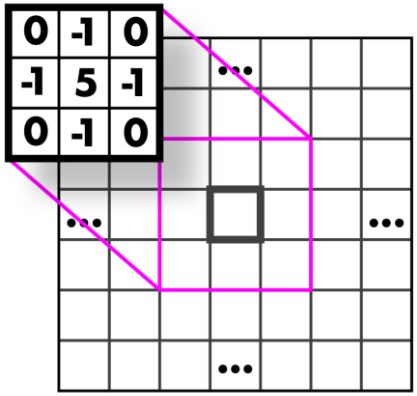
Guess that kernel!



Identity Kernel: Does nothing!

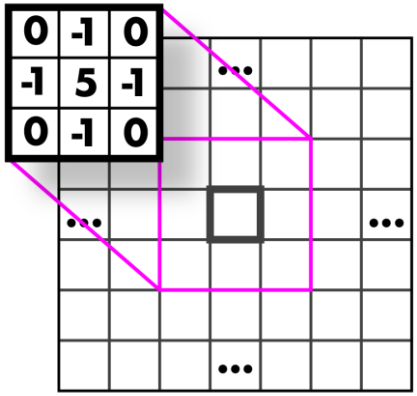


Guess that kernel!



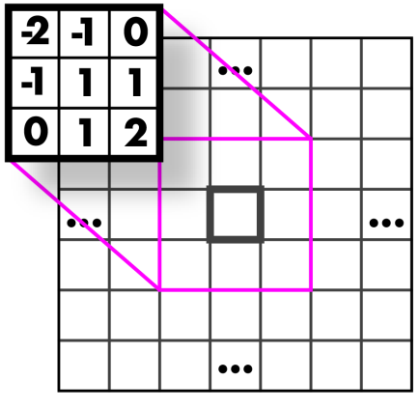
Sharpen Kernel: sharpens!

(applied to all three bands)

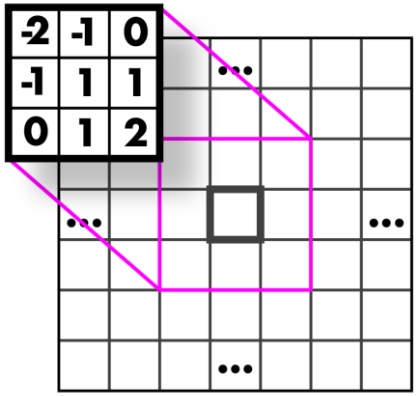


Note: sharpen = highpass + identity!

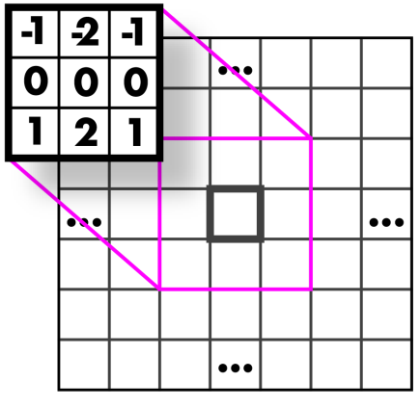
Guess that kernel!

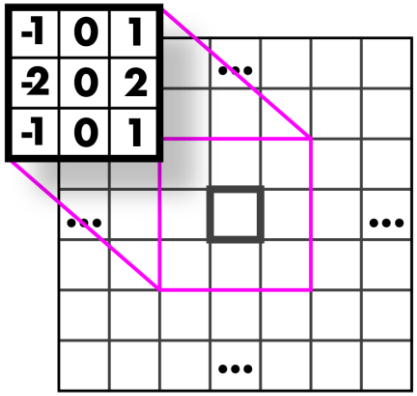


Emboss Kernel: stylin’ (applied to all three bands)

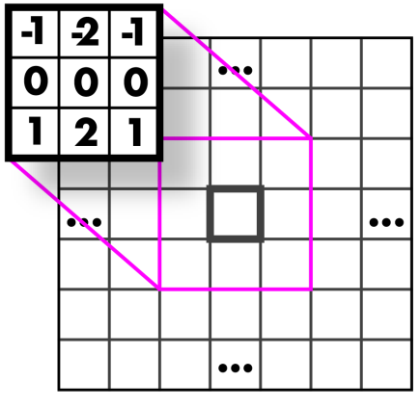


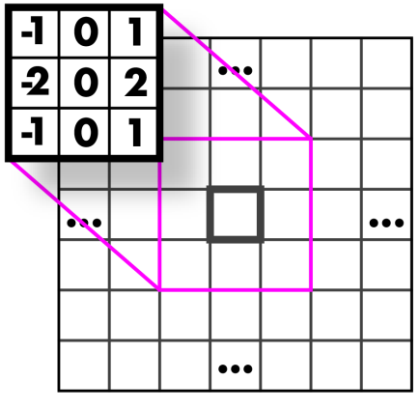
Guess those kernels!



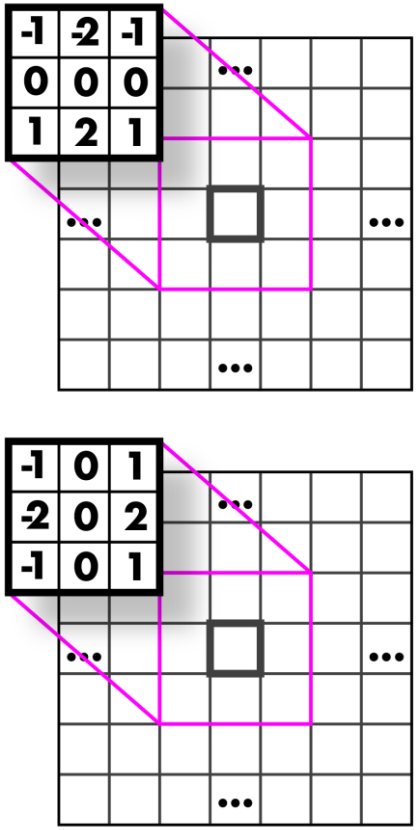


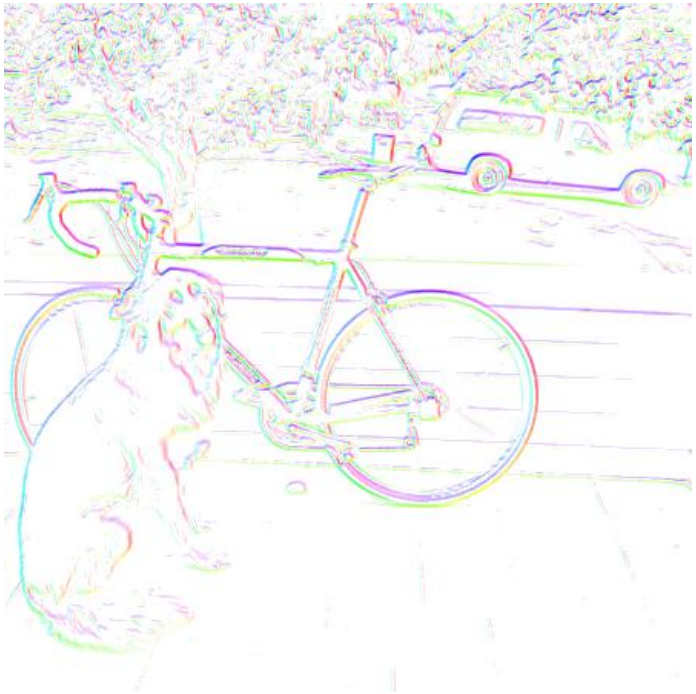
Sobel Kernels: edges (applied to a graytone image and thresholded)



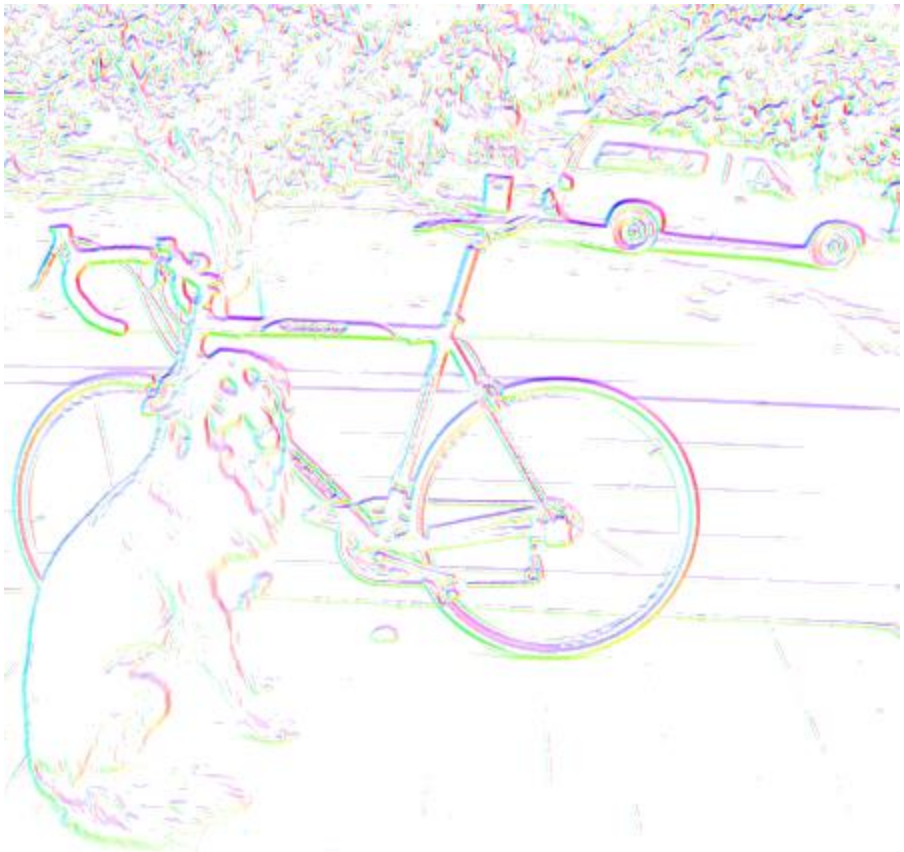


Sobel Kernels: edges and gradient!





Sobel Kernels: edges and gradient!



This visualization is showing the magnitude and direction of the gradient. We will talk further about this when we discuss edges.