Computer Vision

CSE 455
Image Coordinates and Resizing

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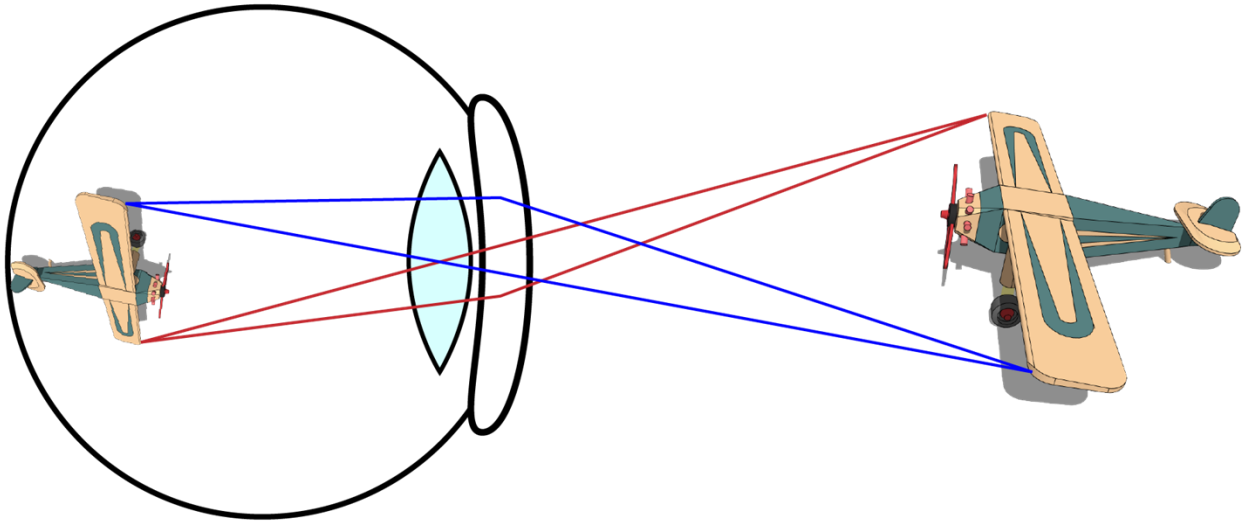
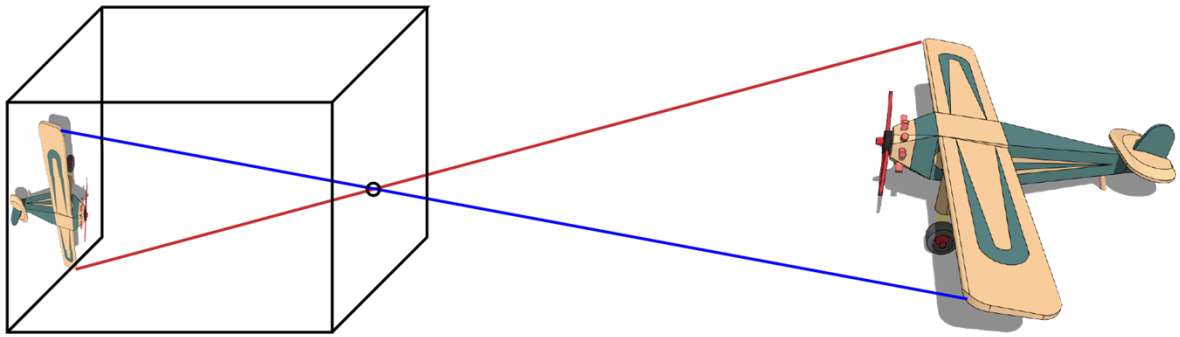
What is an image?

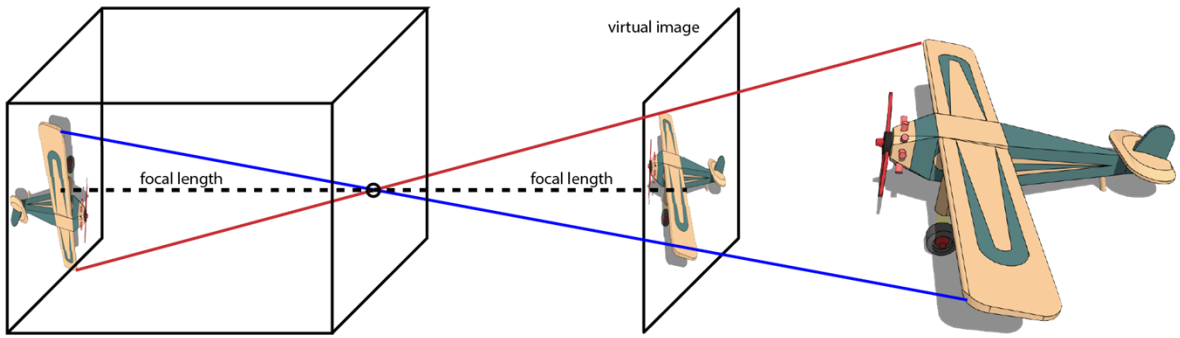
Eyes: projection onto retina



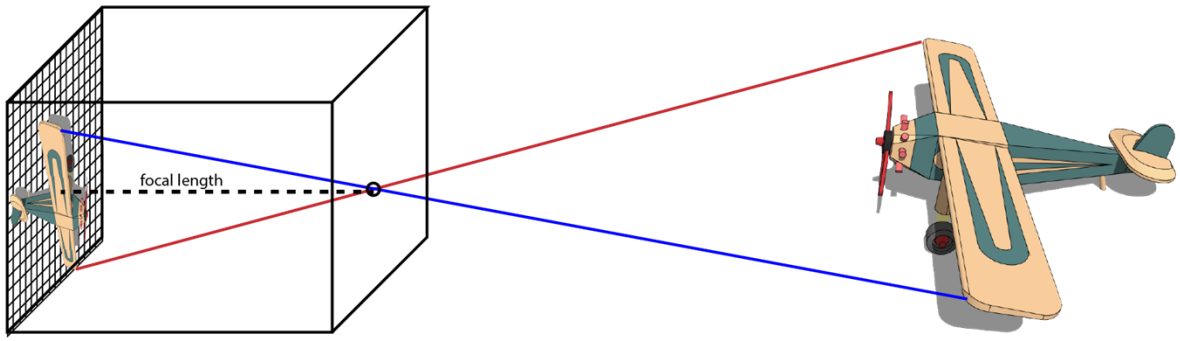
Model: pinhole camera



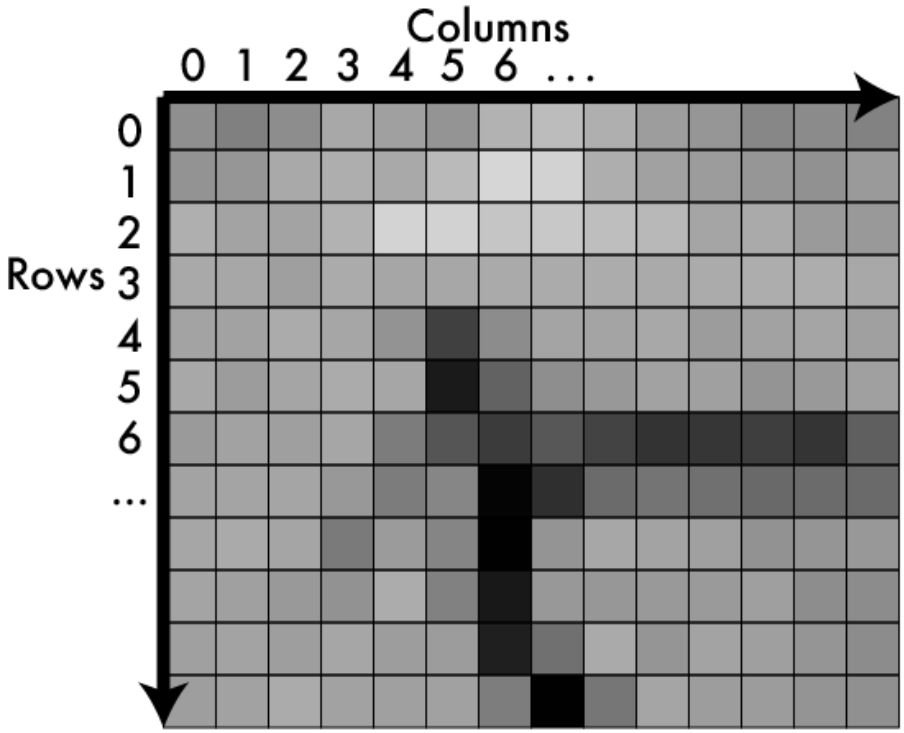
Model: pinhole camera



At each point we record incident light



An image is a matrix of light



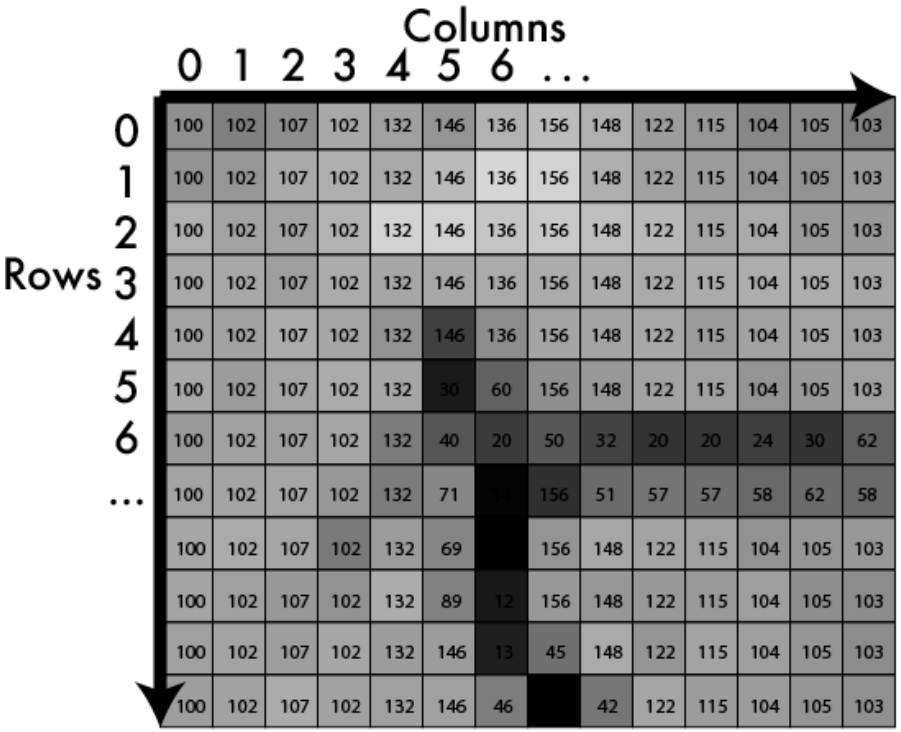
Values in matrix = how much light

Columns

Rows	0	1	2	3	4	5	6	…						
0	100	102	107	102	132	146	136	156	148	122	115	104	105	103
1	100	102	107	102	132	146	136	156	148	122	115	104	105	103
2	100	102	107	102	132	146	136	156	148	122	115	104	105	103
3	100	102	107	102	132	146	136	156	148	122	115	104	105	103
4	100	102	107	102	132	146	136	156	148	122	115	104	105	103
5	100	102	107	102	132	30	60	156	148	122	115	104	105	103
6	100	102	107	102	132	40	20	50	32	20	20	24	30	62
…	100	102	107	102	132	71	[illegible]	156	51	57	57	58	62	58
	100	102	107	102	132	69		156	148	122	115	104	105	103
	100	102	107	102	132	89	12	156	148	122	115	104	105	103
	100	102	107	102	132	146	13	45	148	122	115	104	105	103
	100	102	107	102	132	146	46		42	122	115	104	105	103

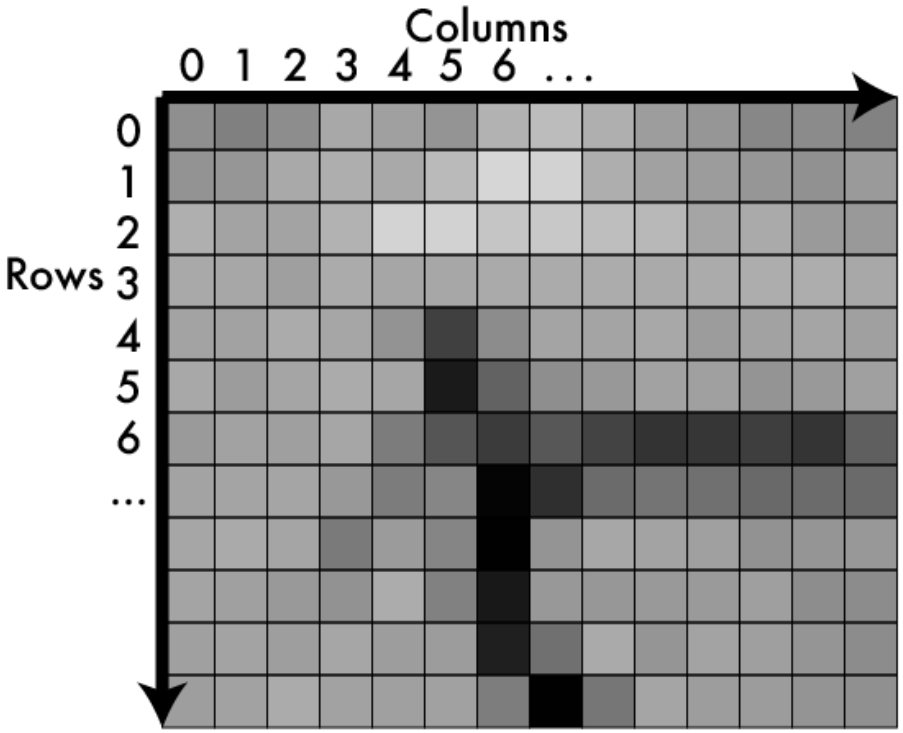
Values in matrix = how much light

- Higher = more light
- Lower = less light
- Bounded
  - No light = 0
  - Sensor/device limit = max
  - Typical ranges:
    - [0-255], fit into byte
    - [0-1], floating point
- Called **pixels**



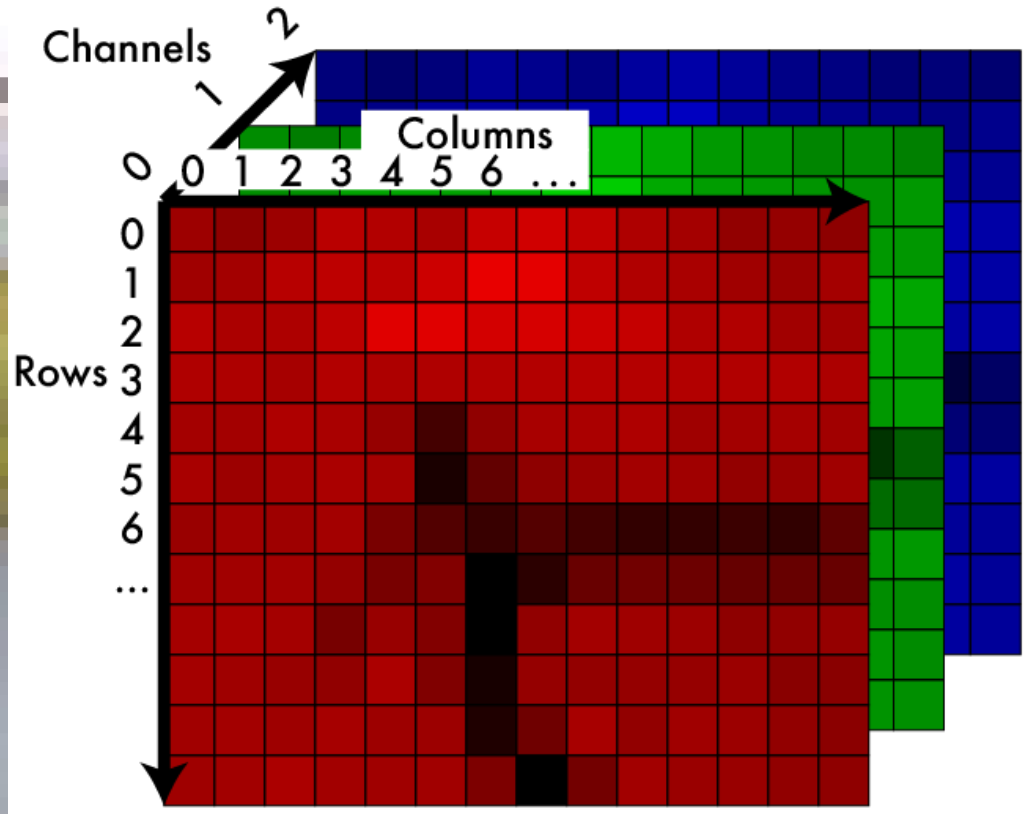
Addressing pixels

- Ways to index:
  - (r,c)
    - Like matrix notation
    - (3,6) is row 3 column 6
  - **(x,y)**
    - Like cartesian coordinates (but from the TOP)
    - (3,6) is column 3 row 6



- **We use (x,y)**
  - So does your homework!
  - Arbitrary
  - Only thing that matters is consistency

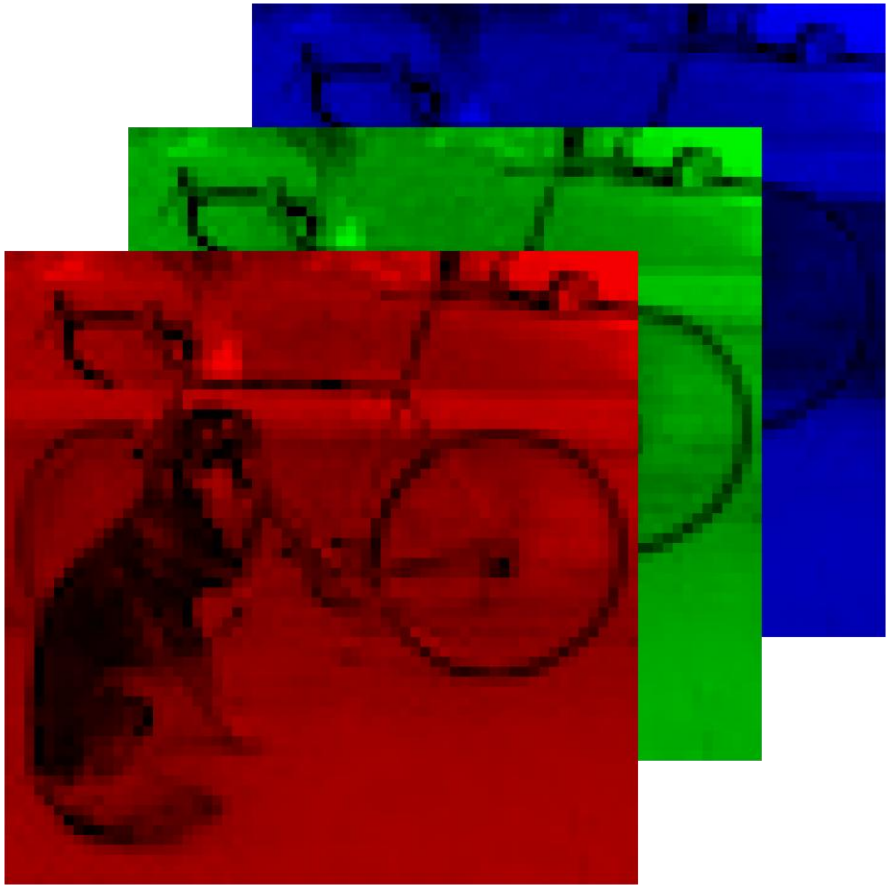
Color image: 3d tensor in colorspace



RGB information in separate “channels”

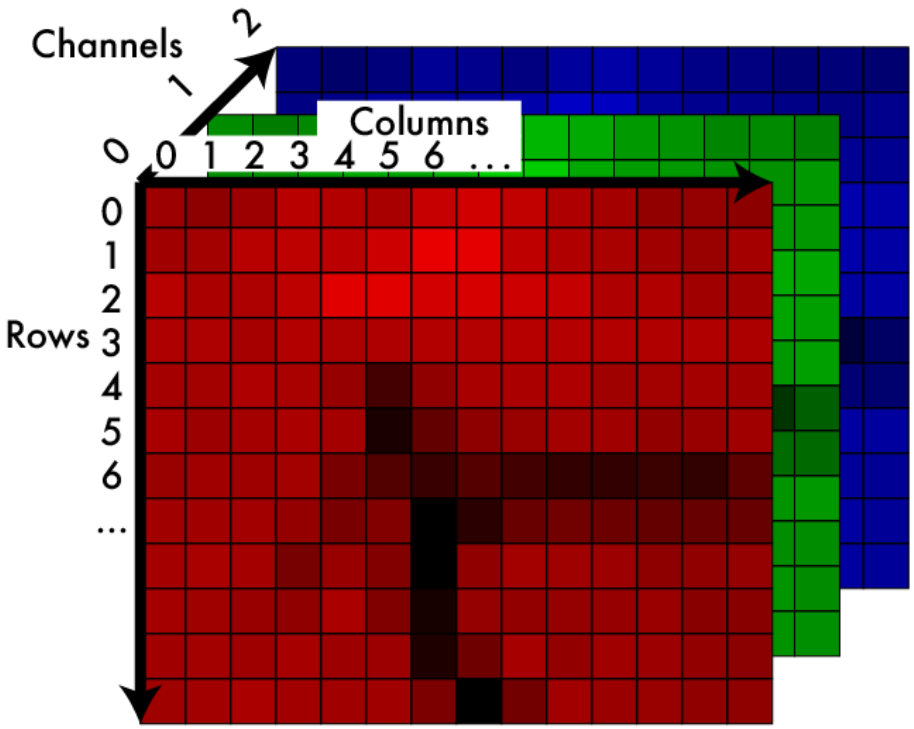
Remember: we can match “real” colors using a mix of primaries.

Each channel encodes one primary. Adding the light produced from each primary mimics the original color.

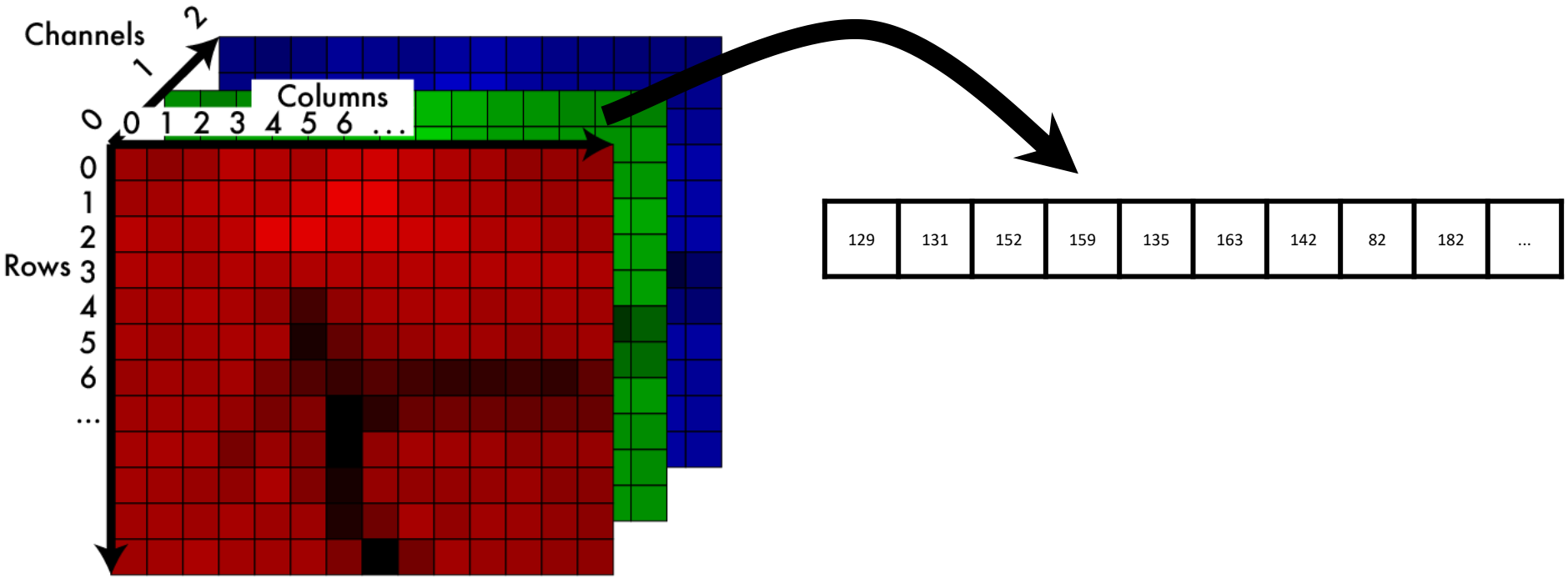


Addressing pixels

- We use (x,y,c)
  - (1,2,0):
    - column 1, row 2, channel 0
- Be consistent
- But do what we do for homeworks :-)
- Also for size:
  - 1920 x 1080 x 3 image:
    - 1920 px wide
    - 1080 px tall
    - 3 channels

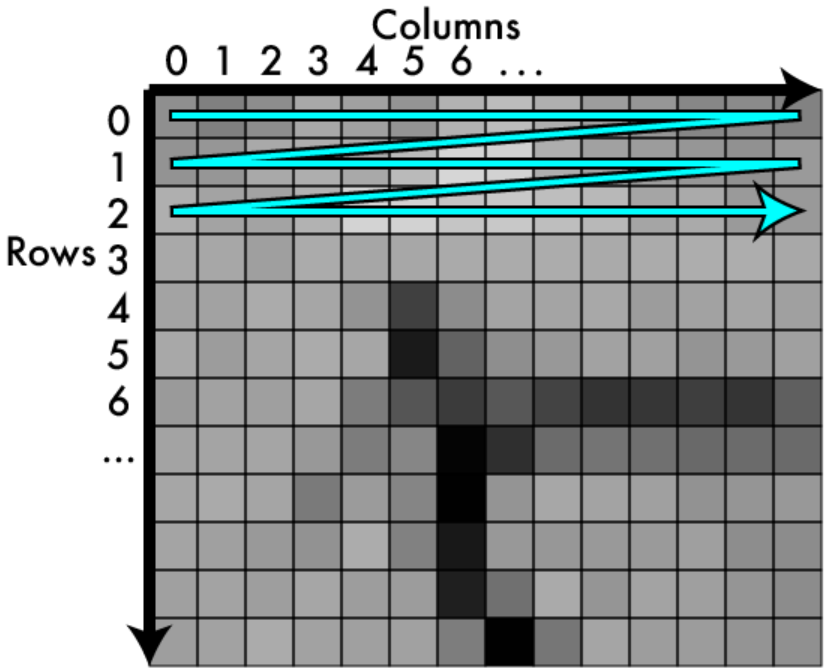


How do we store them?

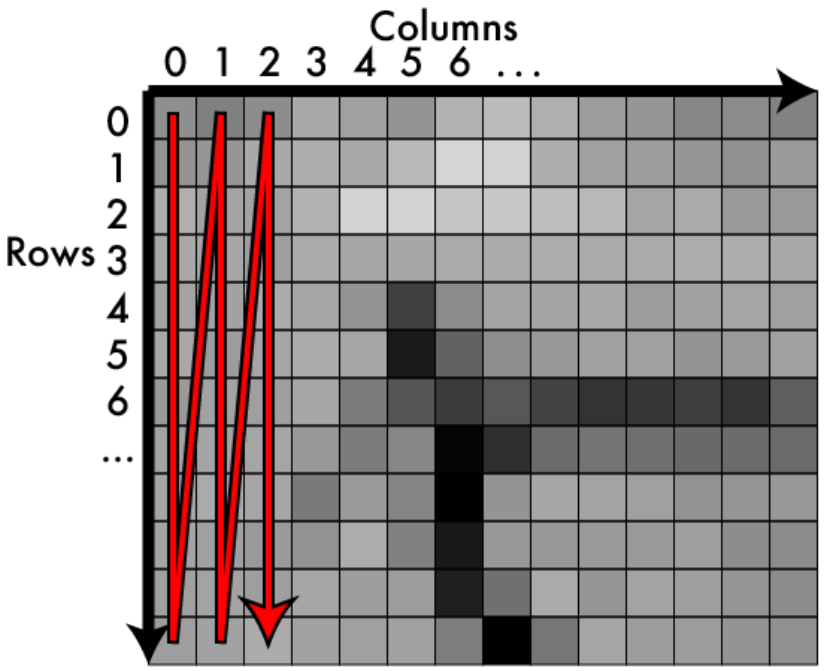


Storage: row major vs column major

Row Major

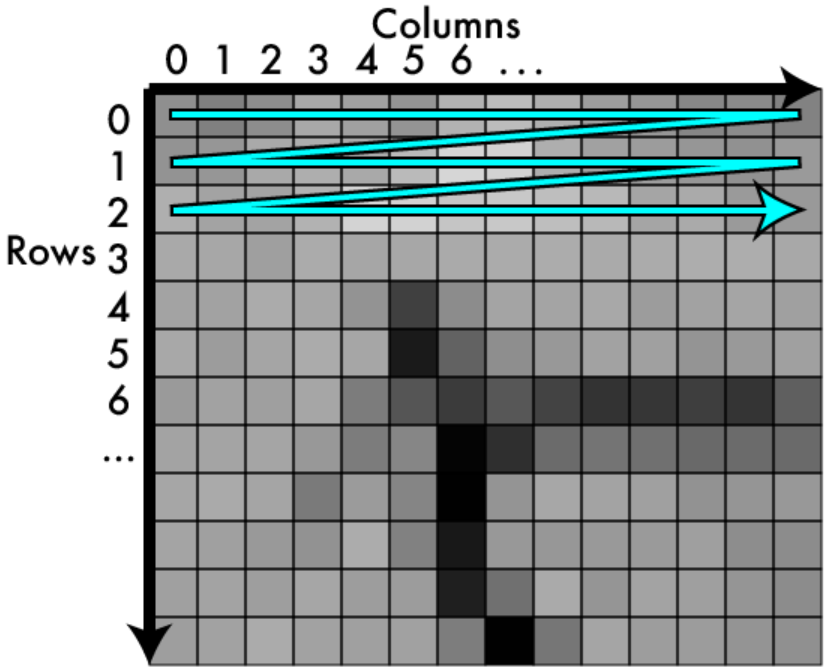


Column Major

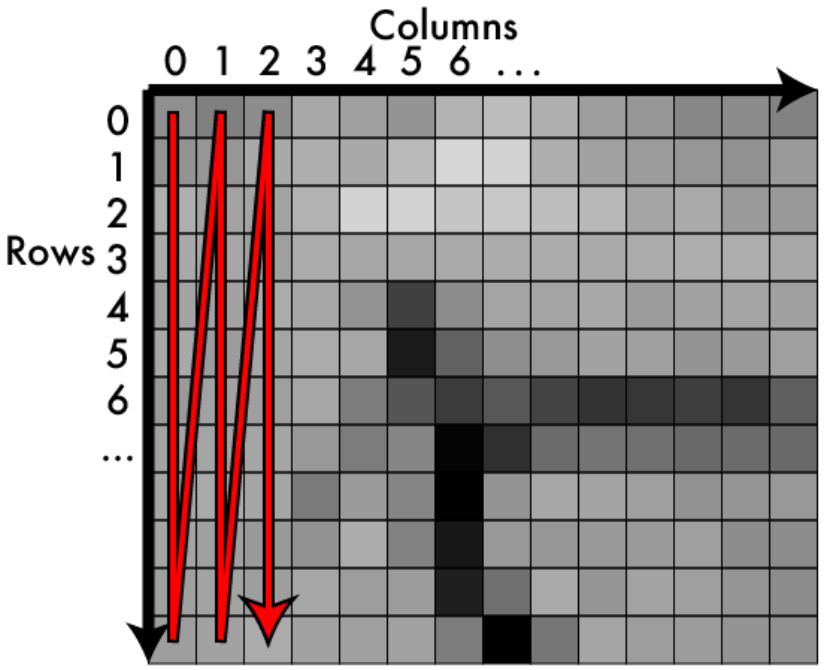


Storage: row major vs column major

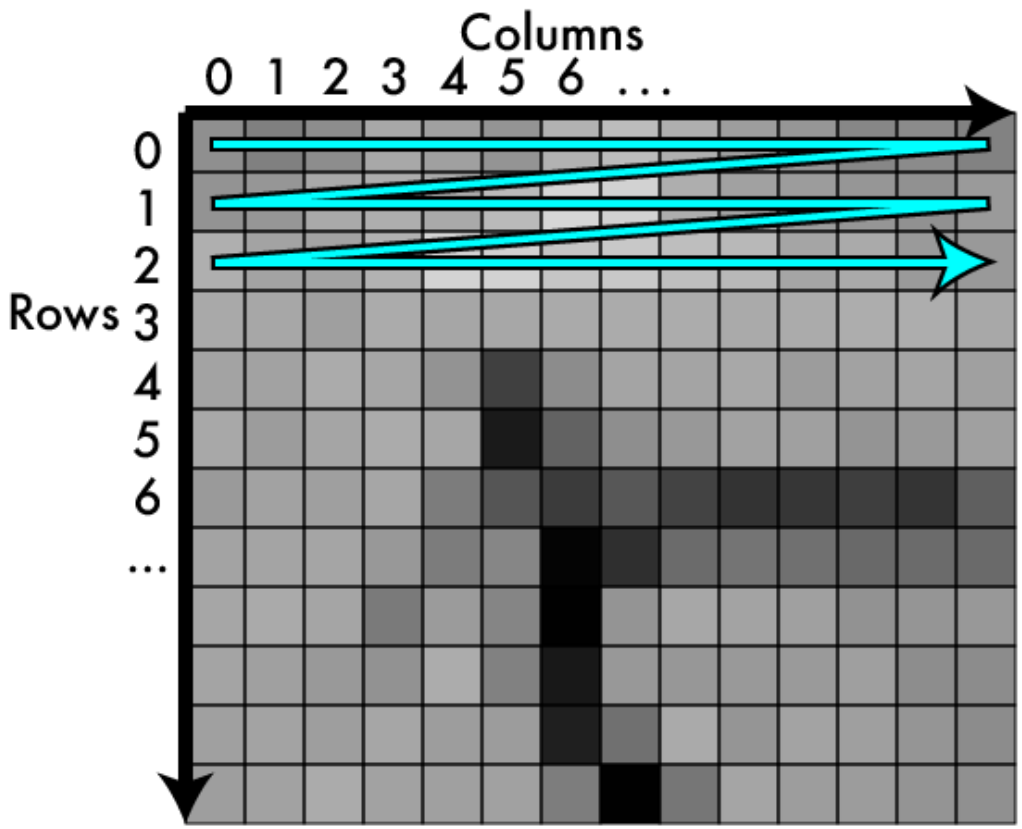
HW



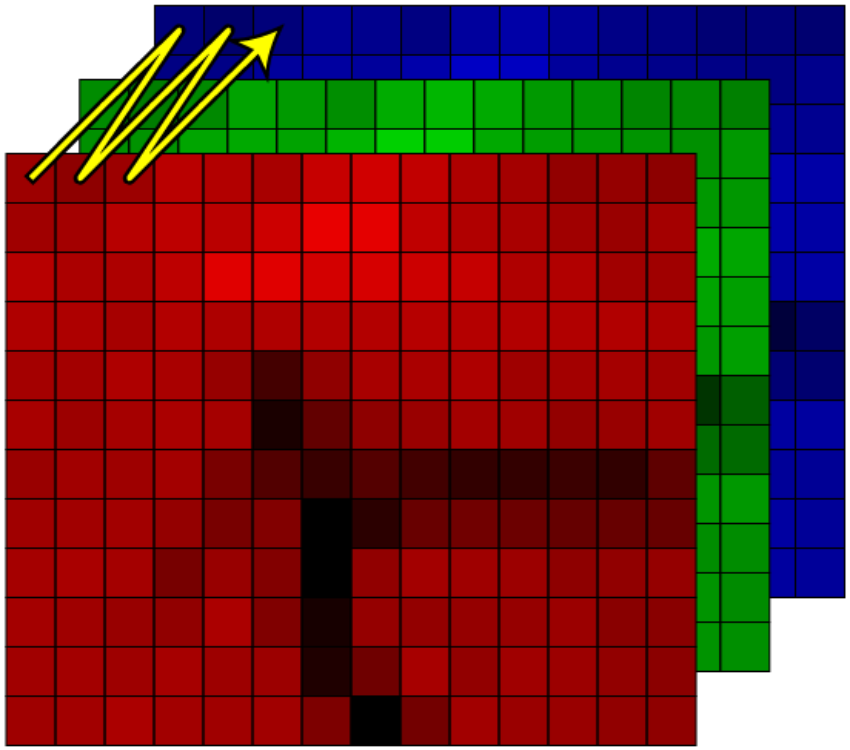
WH

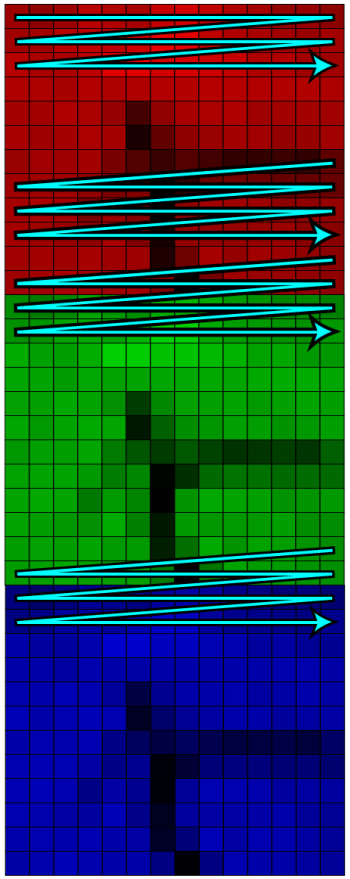


Typically use row-major or HW

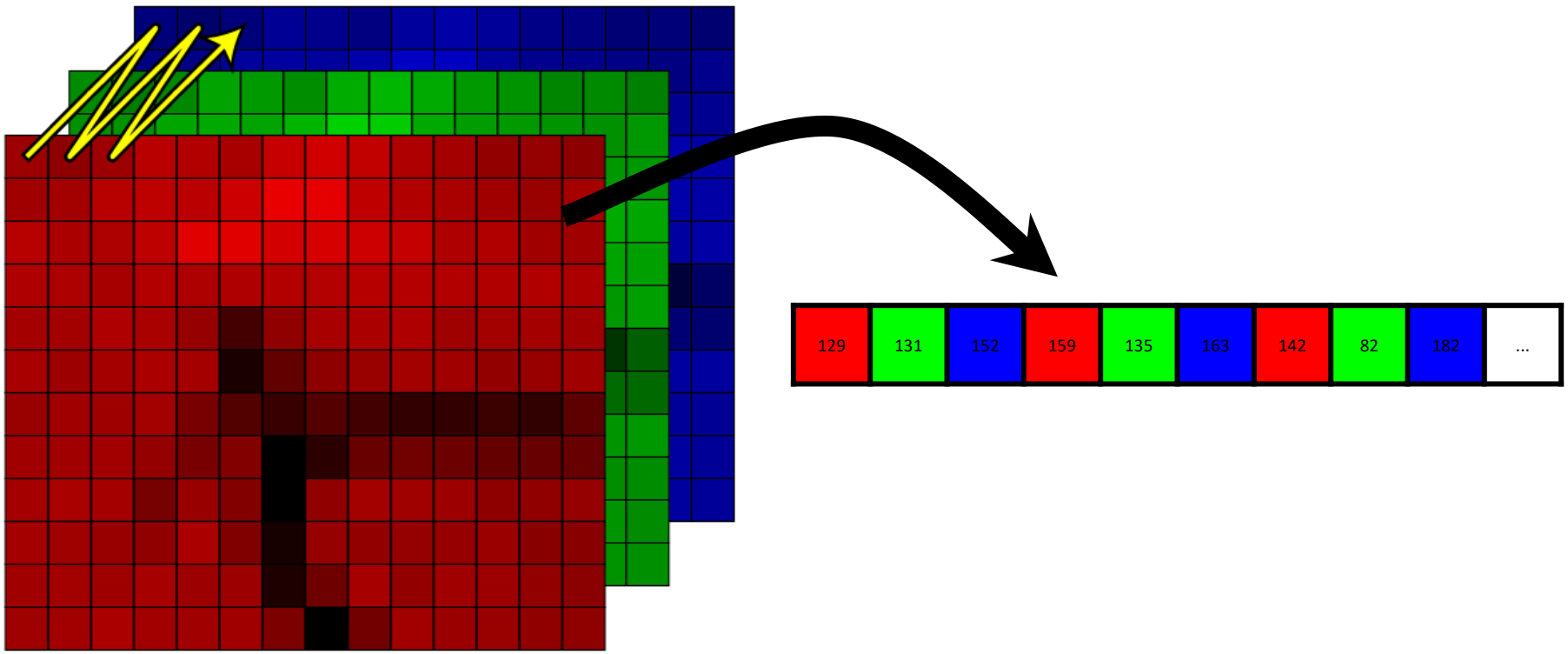


In 3d we have more choices!

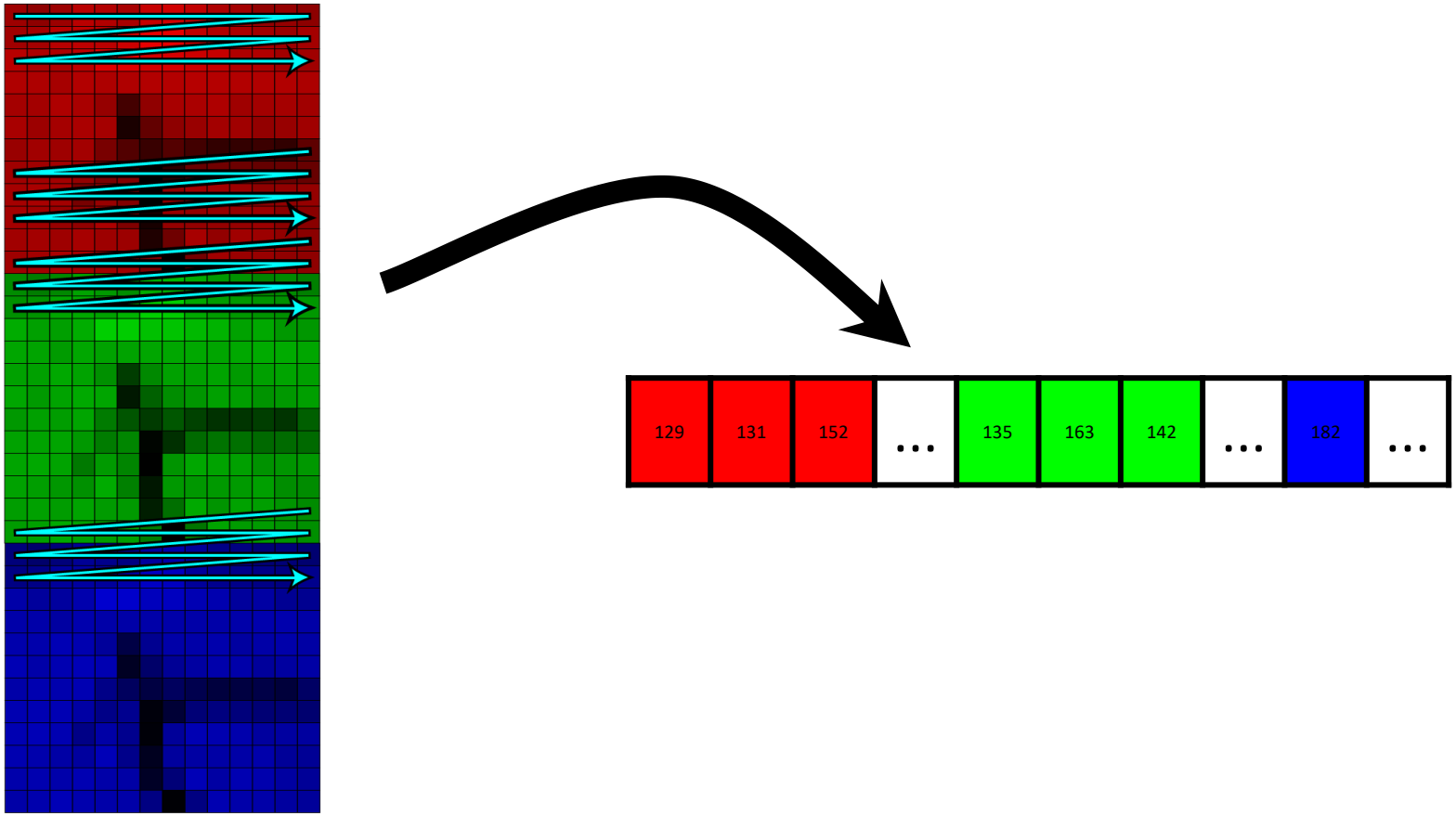




HWC: channels interleaved



CHW: channels separated



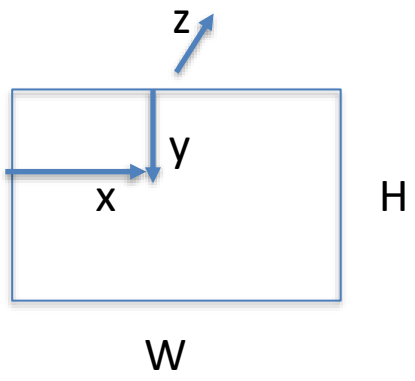
CHW Pop quiz

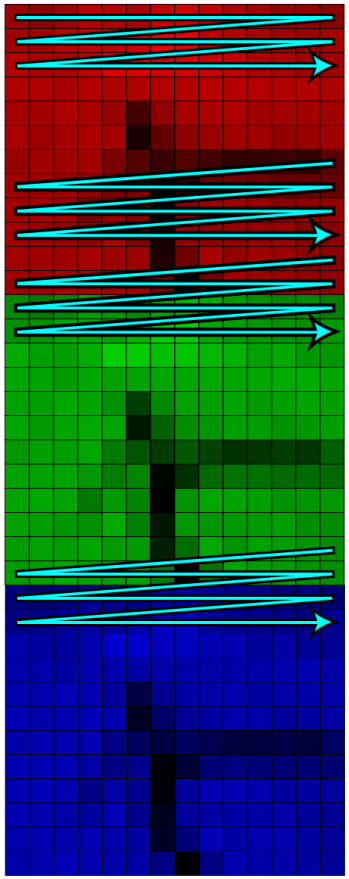
We'll use CHW, it's what a lot of other libraries use.

In an array for a 1920 x 1080 x 3 image what entry would contain the pixel (15,192,2)?

Formula:

x + y*W + z*W*H





CHW Pop quiz

In an array for a 1920 x 1080 x 3 image what entry would contain the pixel (15,192,2)?

In general for (x,y,z) of image (W,H,C)

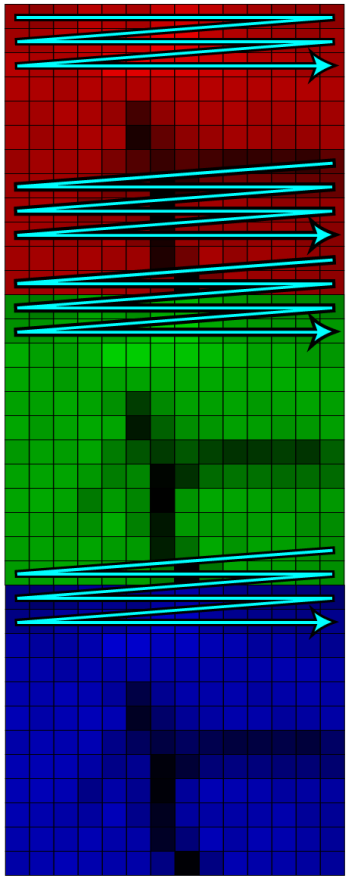
x + y*W + z*W*H

15 + 192*1920 + 2*1920*1080 = 4,515,855

Remember, everything is 0 indexed

Where does (0,0,0) go?

Position 0 + 0 + 0 = 0



In your homework

```
class Image:
        w: int
        h: int
        c: int
        data: np.ndarray
```

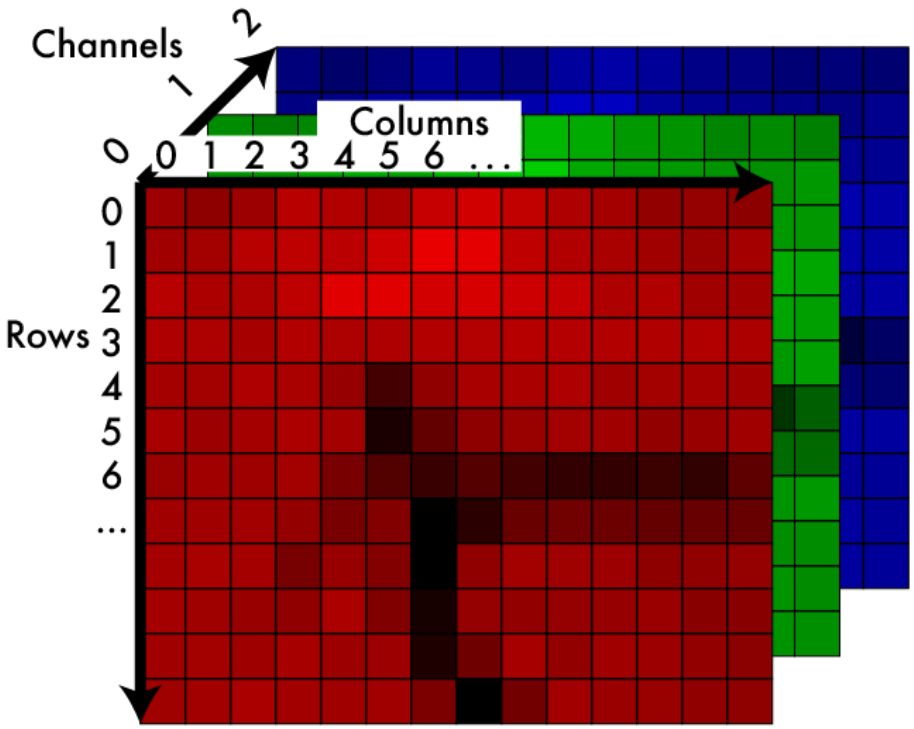


Image interpolation and resizing

An image is kinda like a function

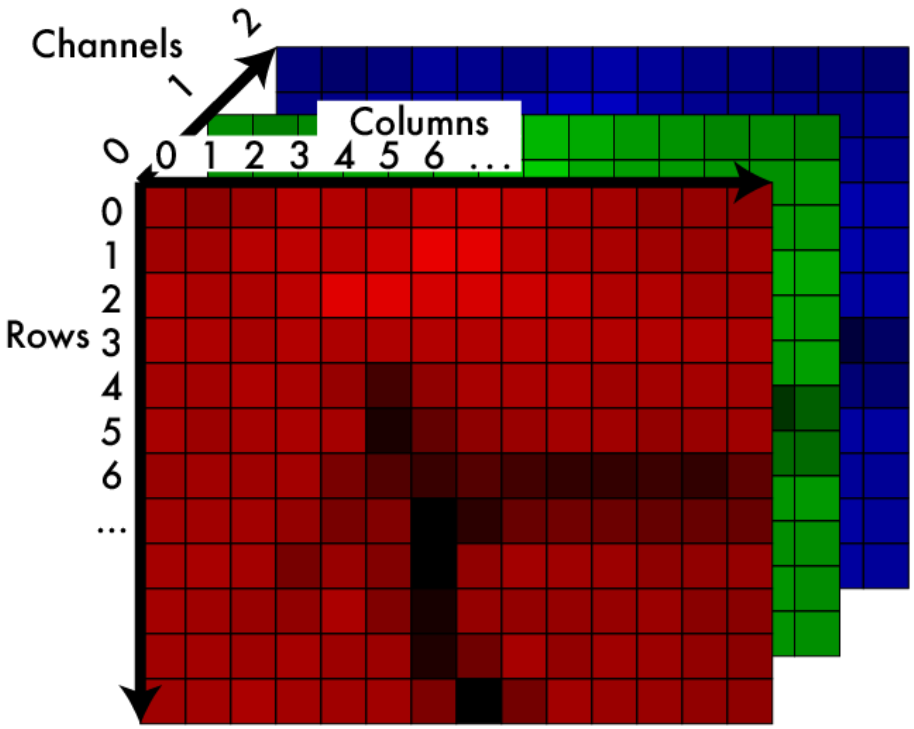
An image is a mapping from indices to pixel value:

- Im: I x I x I -> R

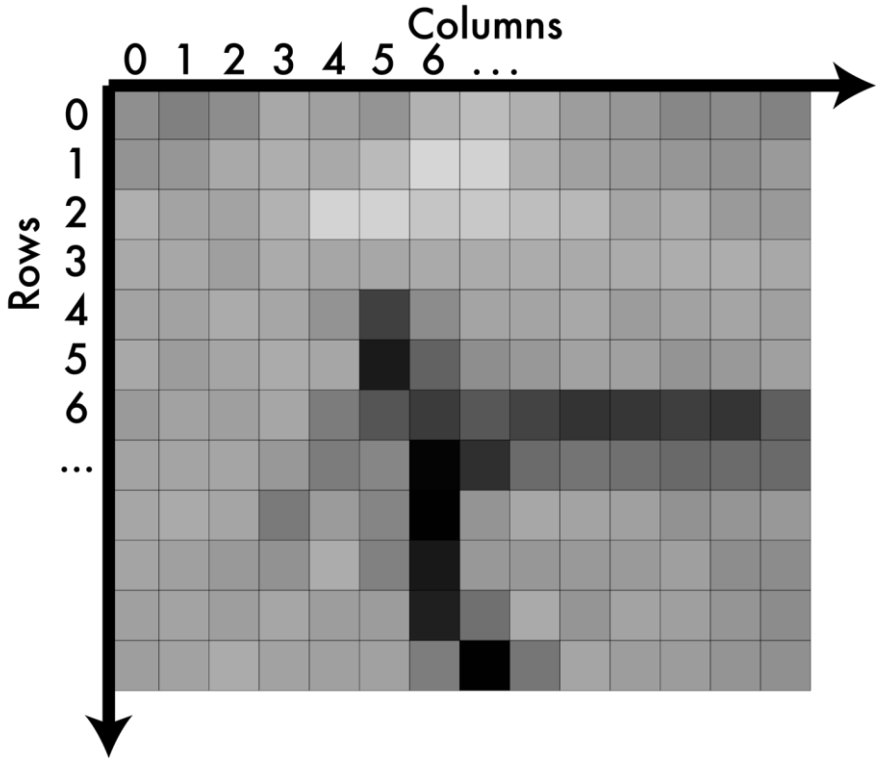
We may want to pass in

non-integers:

- Im': R x R x I -> R

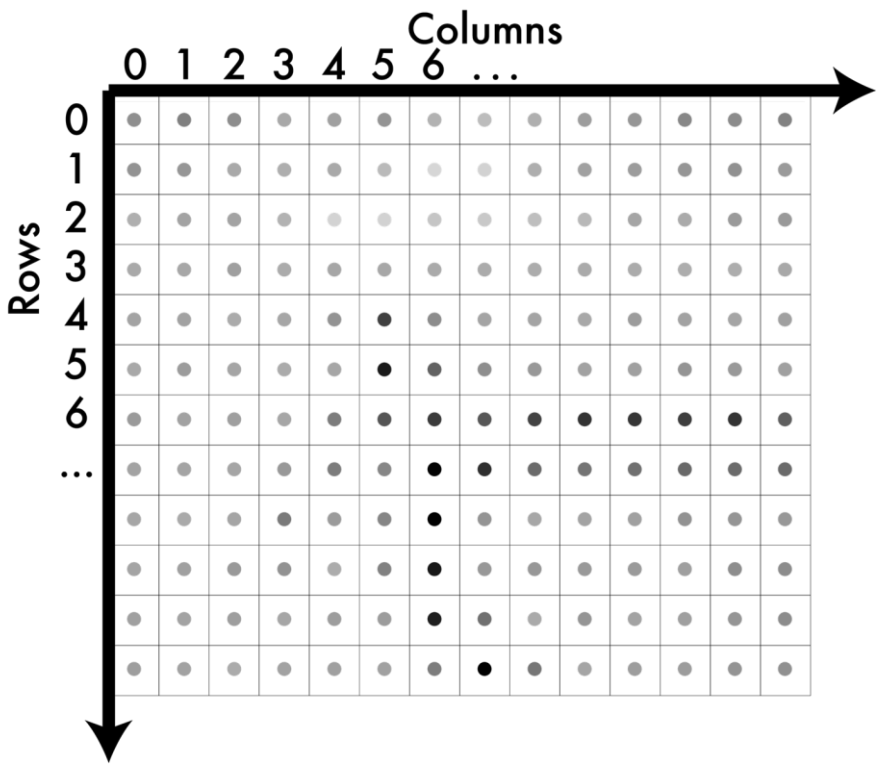


A note on coordinates in images



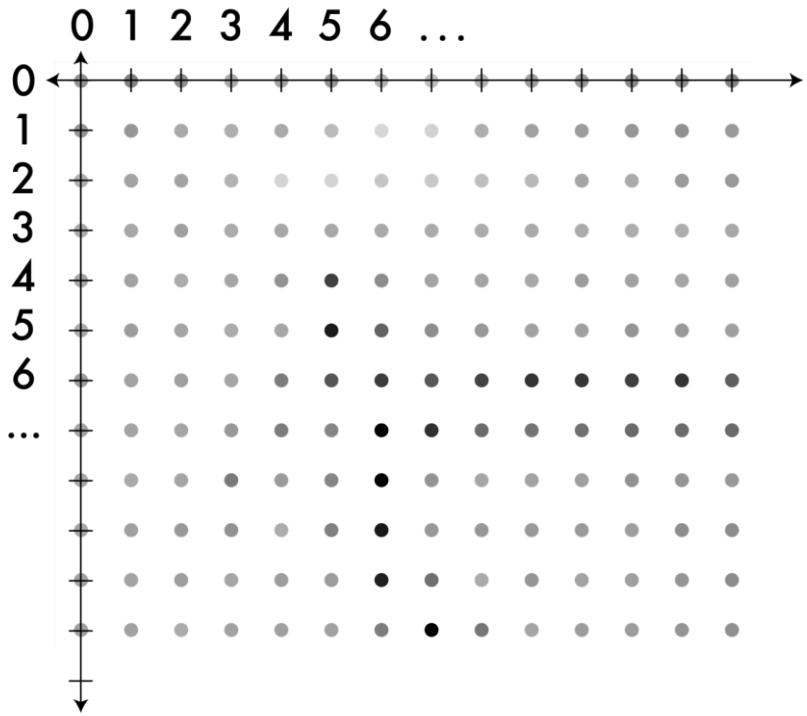
integer pixels

A note on coordinates in images



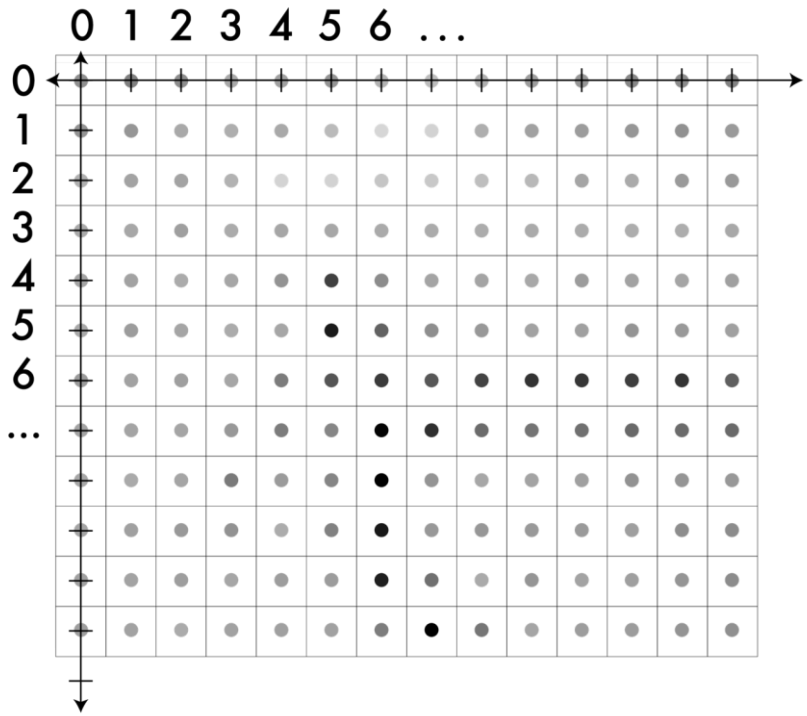
We can think of their values as being at the centers.

A note on coordinates in images



Now we can move to a real coordinate system.

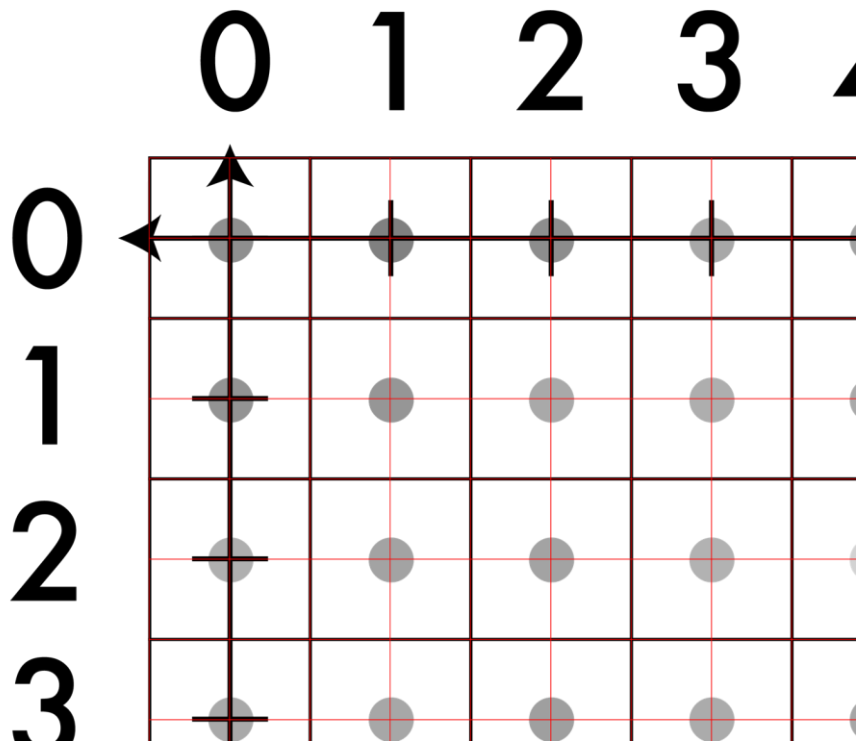
A note on coordinates in images



On the image

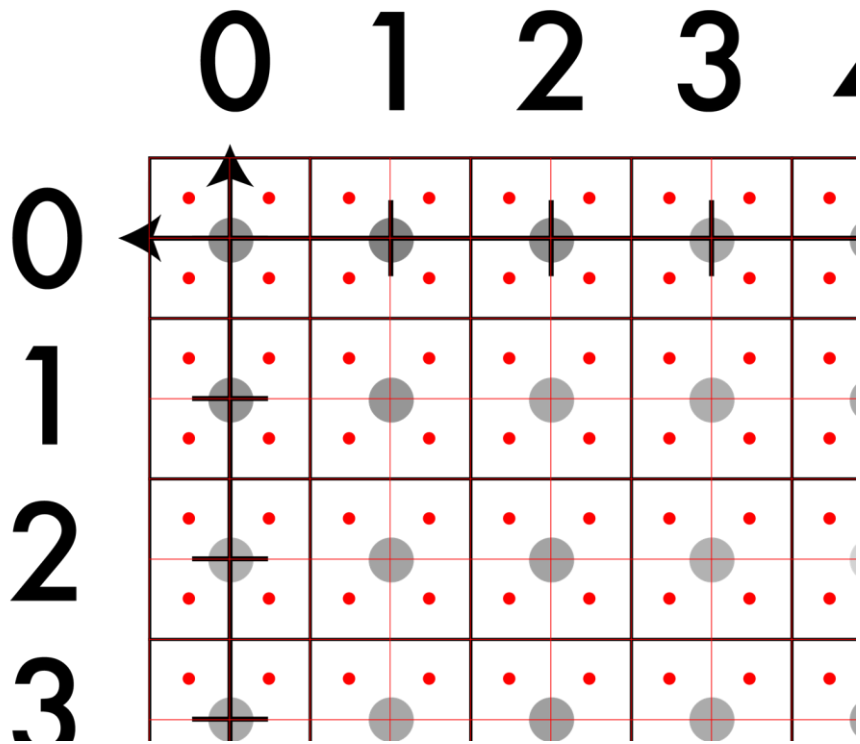
A note on coordinates in images

So, the value of the pixel (x,y) is now centered at (x,y).



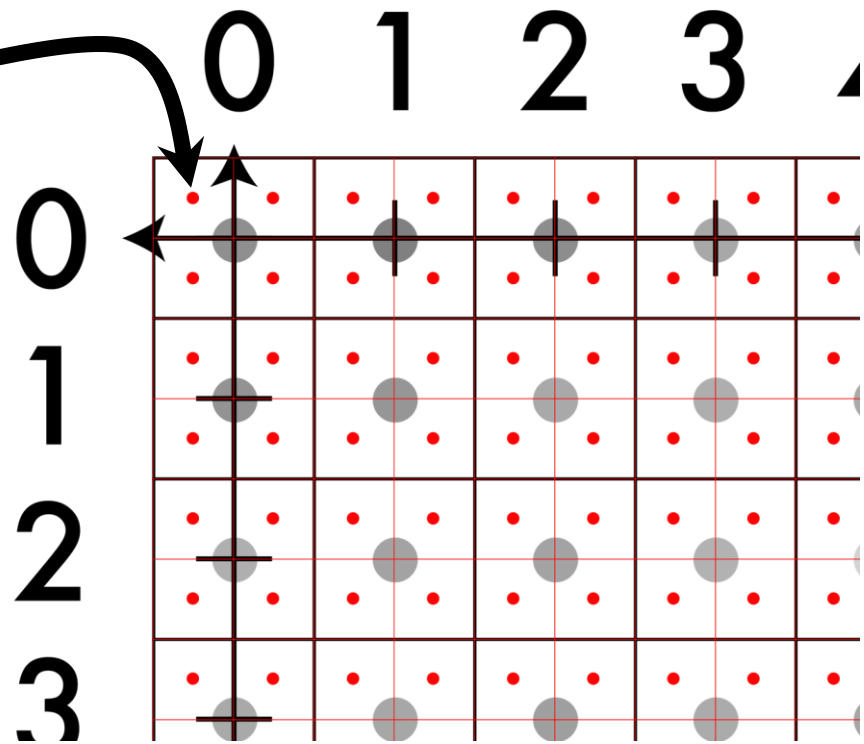
A note on coordinates in images

But there are other real-valued points.



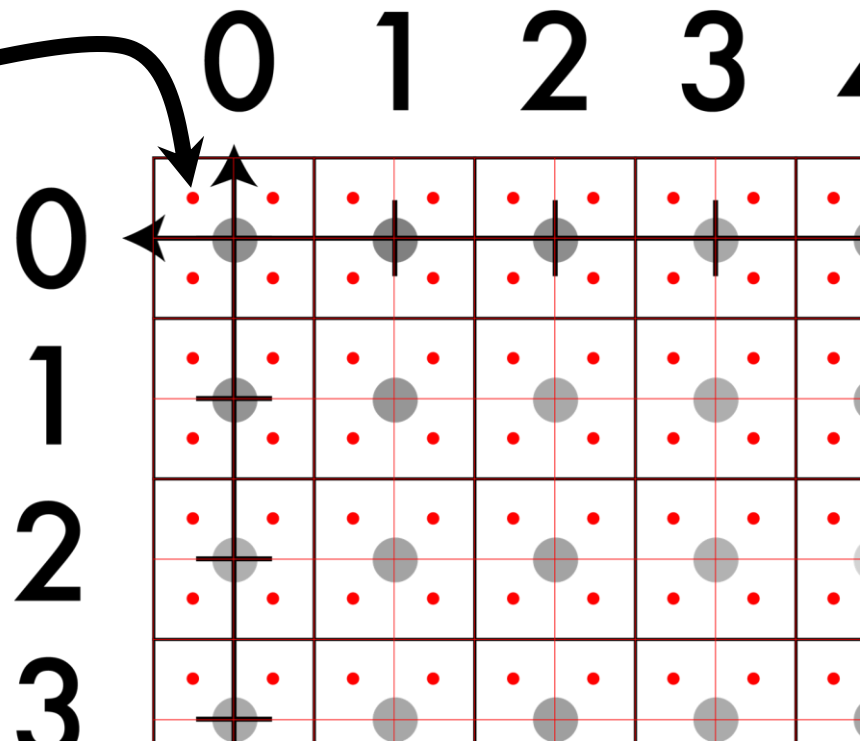
A note on coordinates in images

This point is:
(-.25, -.25)



Just be careful

This point is:
(-.25, -.25)



Interpolation

- How do we find out the VALUE of a non-integer point, when the image only comes with integer points, ie (25,45,3).
- For our assignment:
  1. Nearest-Neighbor Interpolation
  2. Bilinear Interpolation

Nearest neighbor: what it sounds like

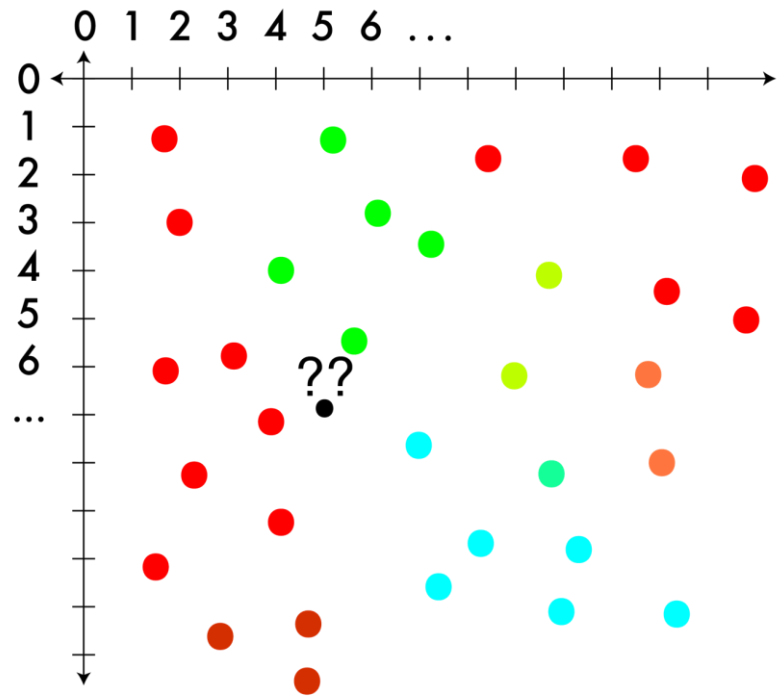
f(x,y,z) = Im(round(x), round(y), z)

- Looks blocky
- Common pitfall: Integer division rounds down in C/Python
- Note: z is still int

Triangle interpolation: for less structured image (alternate approach)

Sometimes you have a regular grid, sometimes you don't.

When you don't, you can look for triangles!



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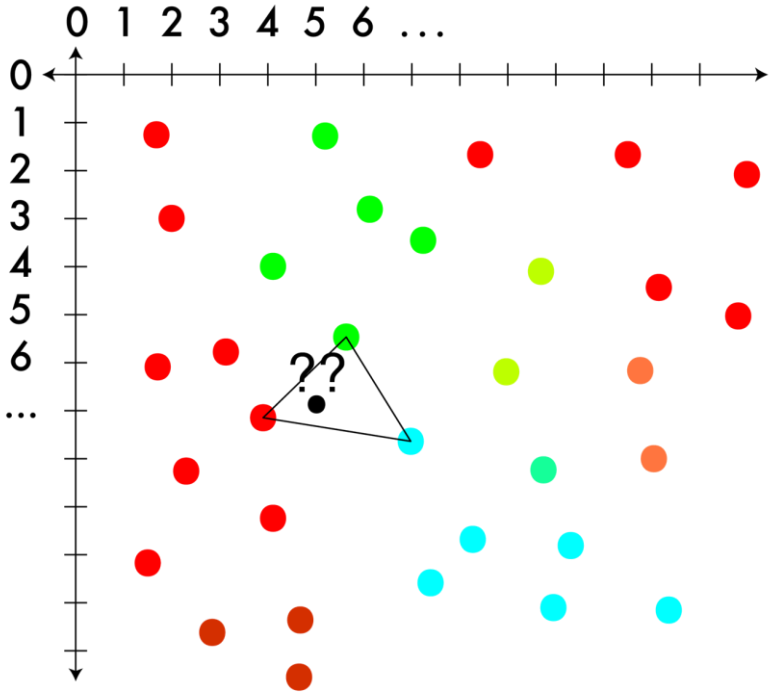

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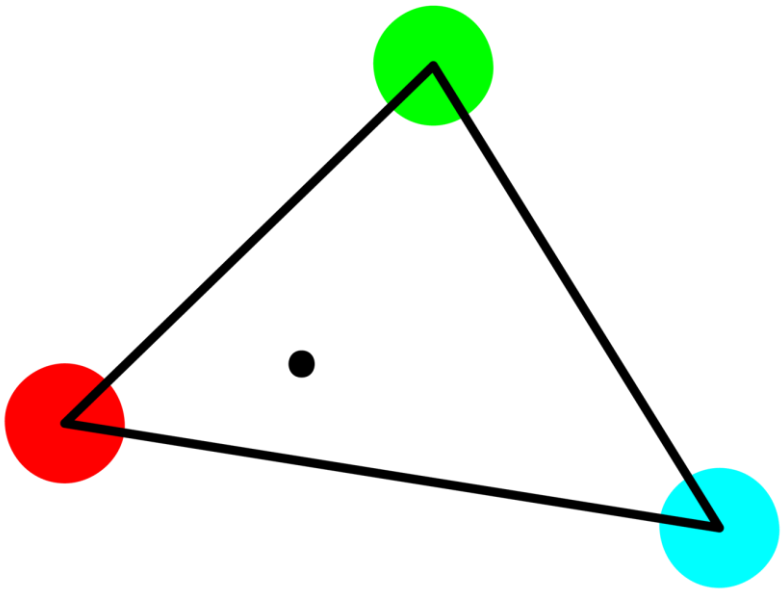

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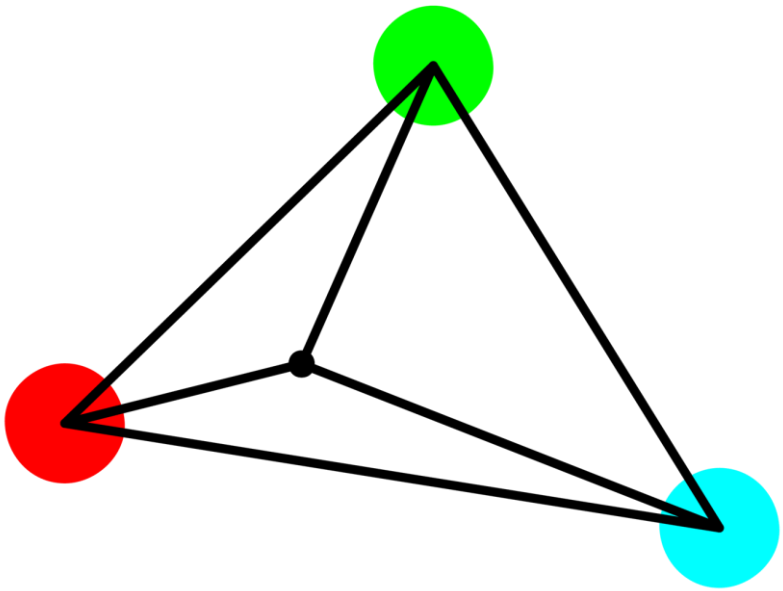


Triangle interpolation: for less structured image

Weighted sum using triangles:

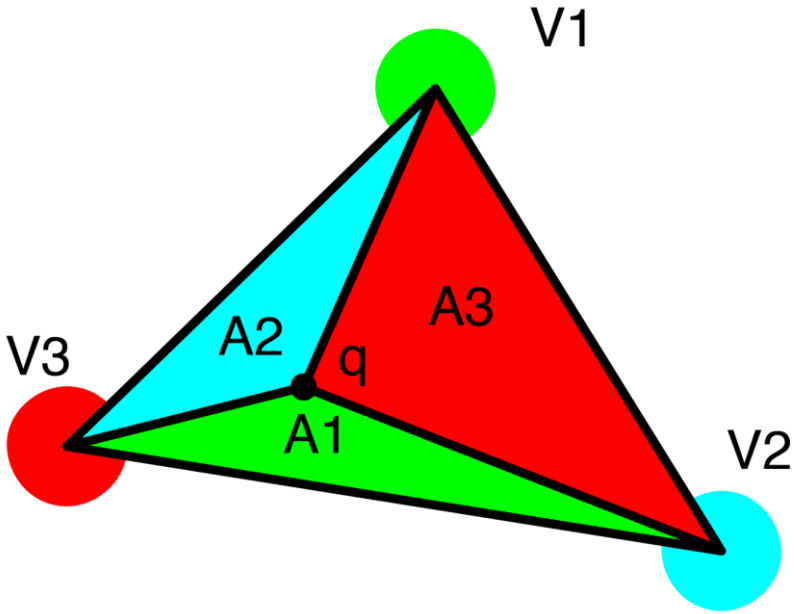
Q = V1*A1 + V2*A2 + V3*A3

WHY?

V1 is the furthest from q and A1 gives the smallest area.

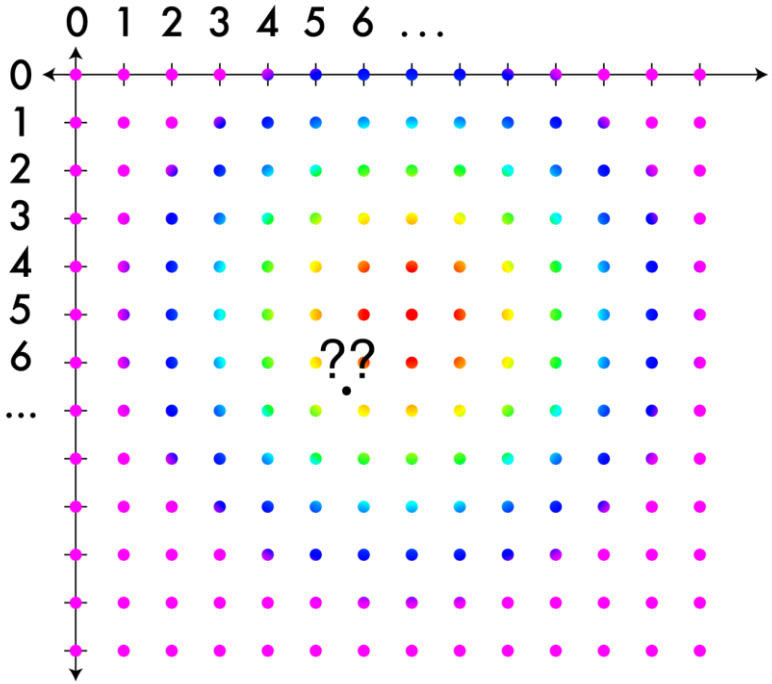
V2 is next furthest from 1 and A2 gives the next smallest area…

Should normalize this based on total area, but we won't use this.



Bilinear interpolation: for grids, pretty good; easier than triangles

This time find the closest pixels in a box



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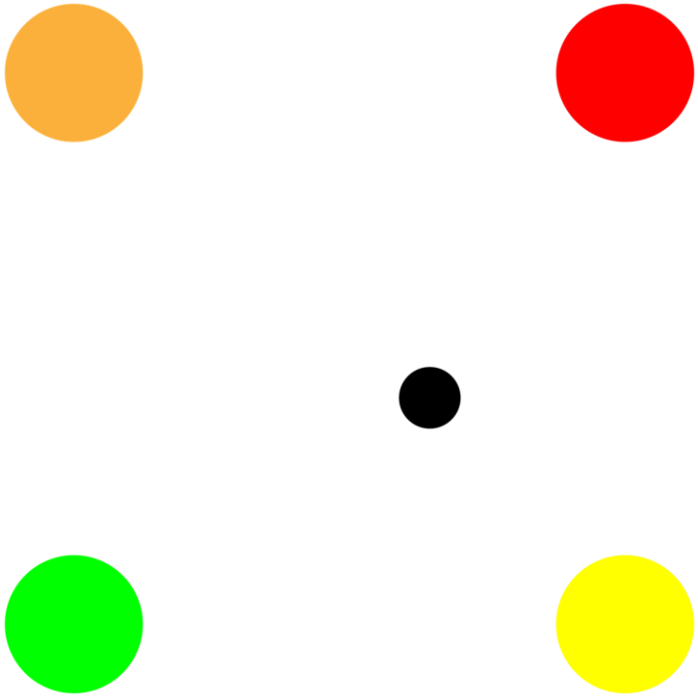

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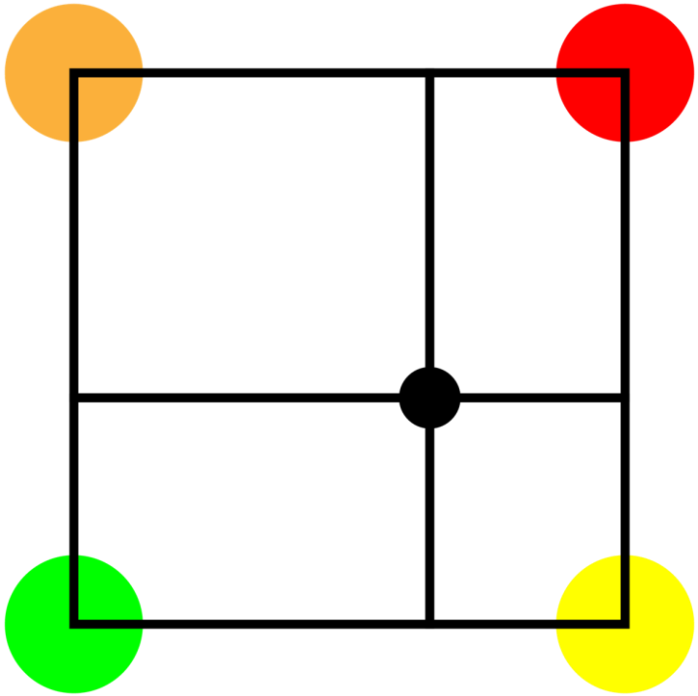
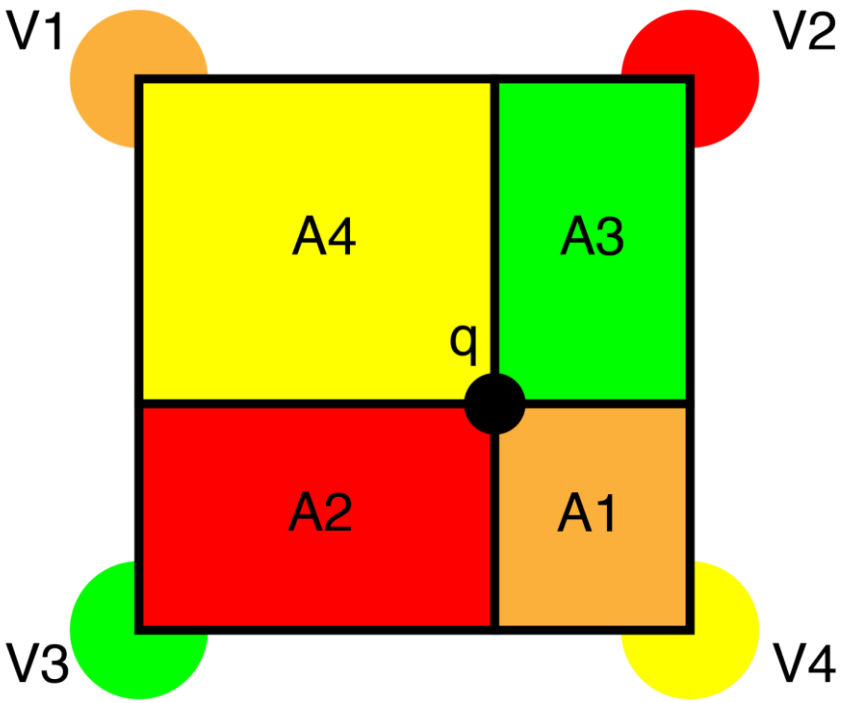


Bilinear interpolation: for grids, pretty good

This time find the closest pixels in a box

Same plan, weighted sum based on area of opposite rectangle

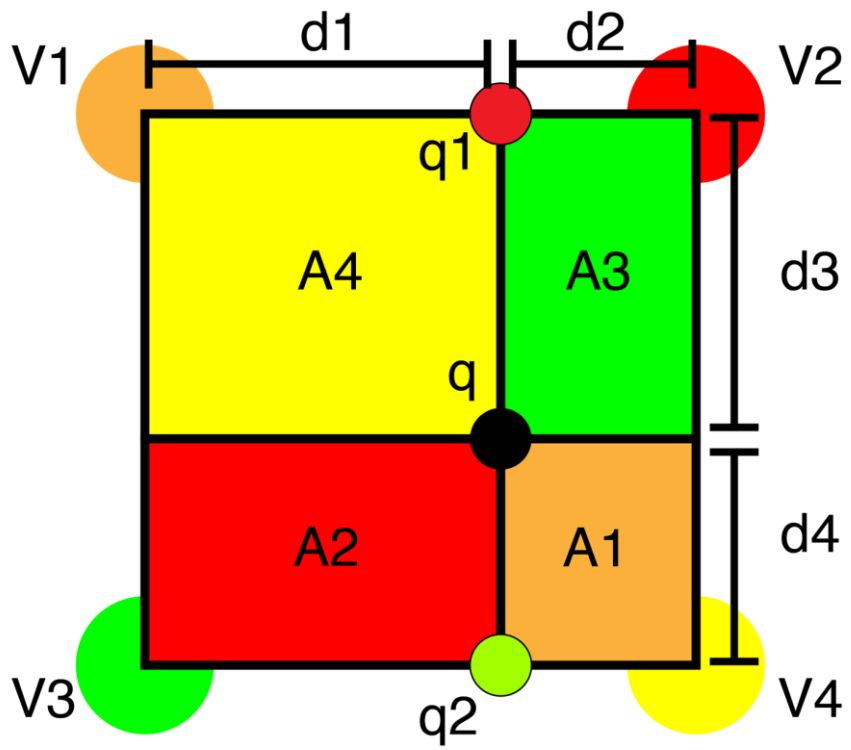
Q = V1*A1 + V2*A2 + V3*A3 + V4*A4



Bilinear interpolation: for grids, pretty good

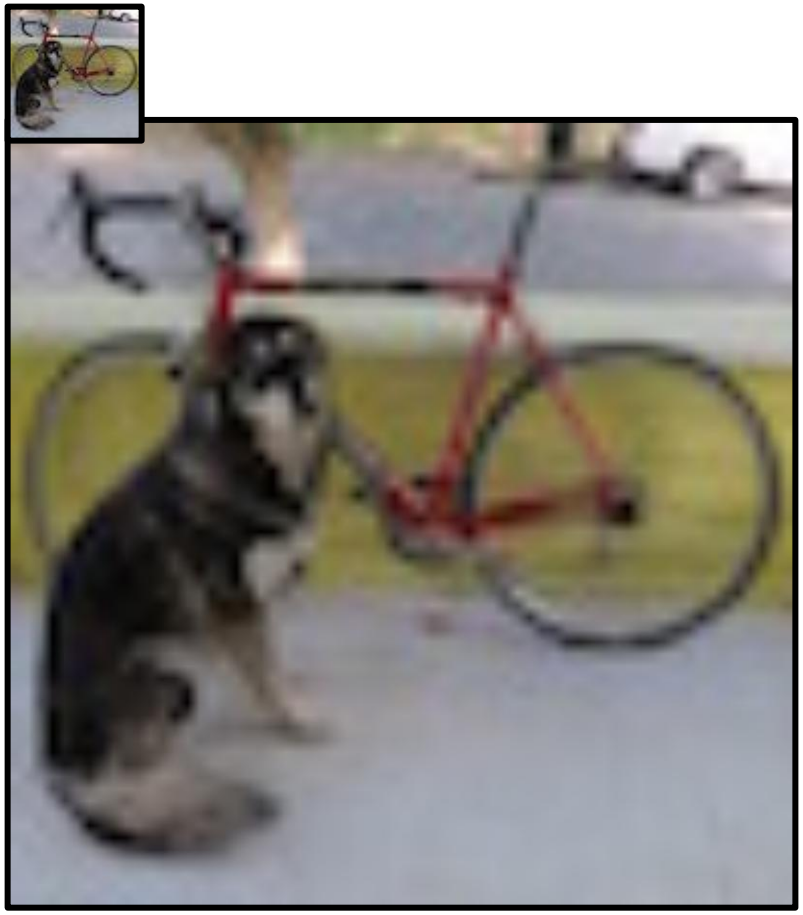
A1 = d2*d4
A2 = d1*d4
A3 = d2*d3
A4 = d1*d3

q = V1*A1 + V2*A2 + V3*A3 + V4*A4



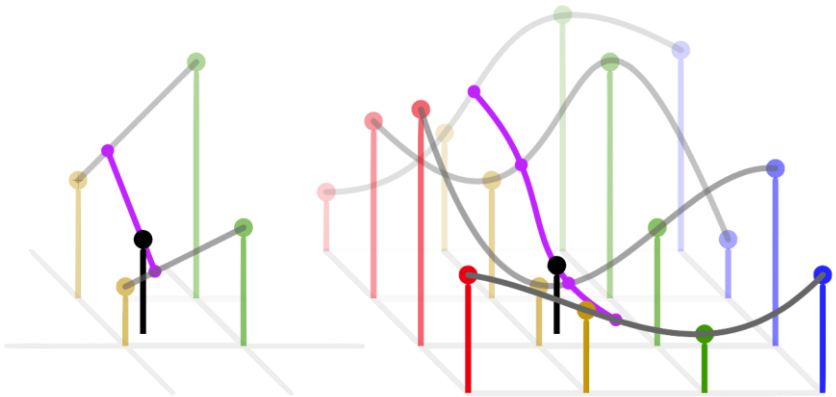
Bilinear interpolation: for grids, pretty good

- Smoother than NN
- More complex
  - 4 lookups
  - Some math
- Often the right tradeoff of speed vs final result



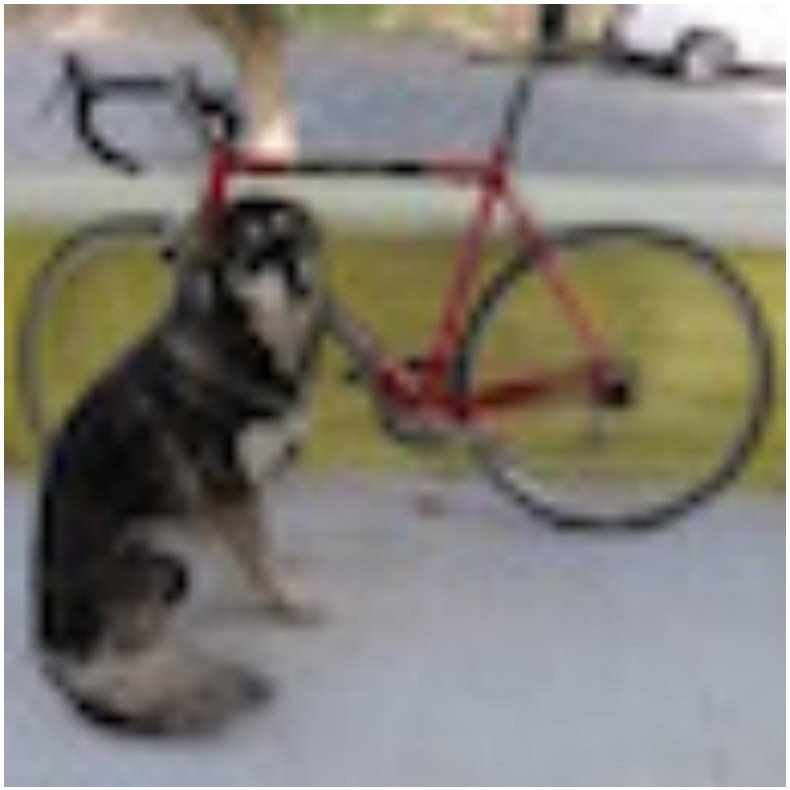
Bicubic sampling: more complex, maybe better?

- A cubic interpolation of 4 cubic interpolations
- Smoother than bilinear, no “star”
- 16 nearest neighbors
- Fit 3rd order poly:
  - f(x) = a + bx + cx^2 + dx^3
- Interpolate along axis
- Fit another poly to interpolated values

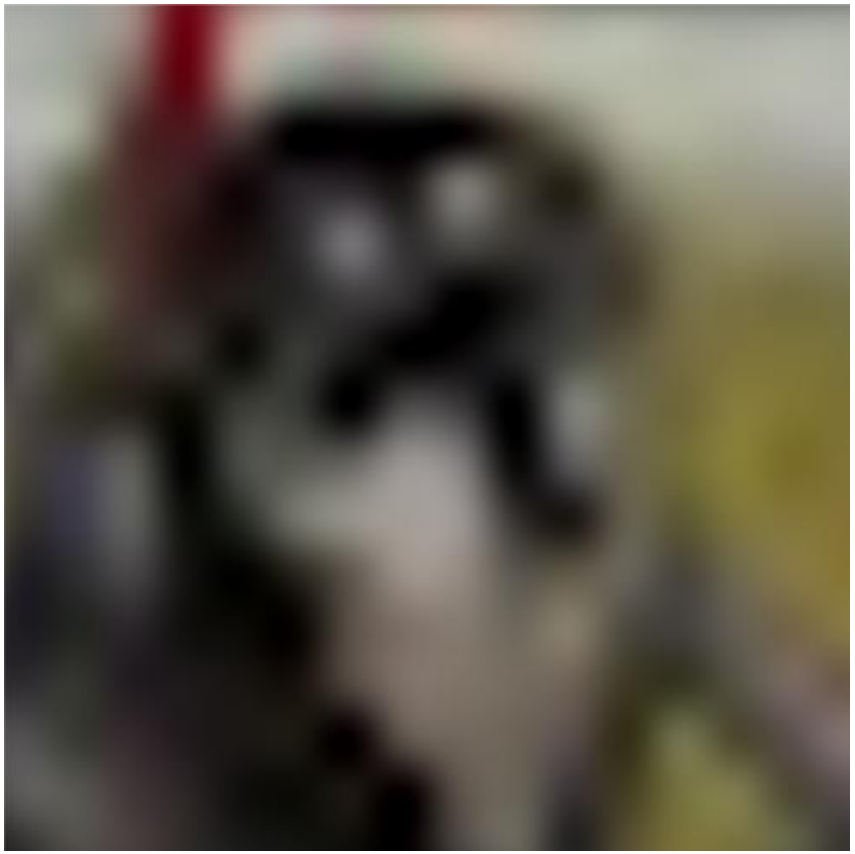


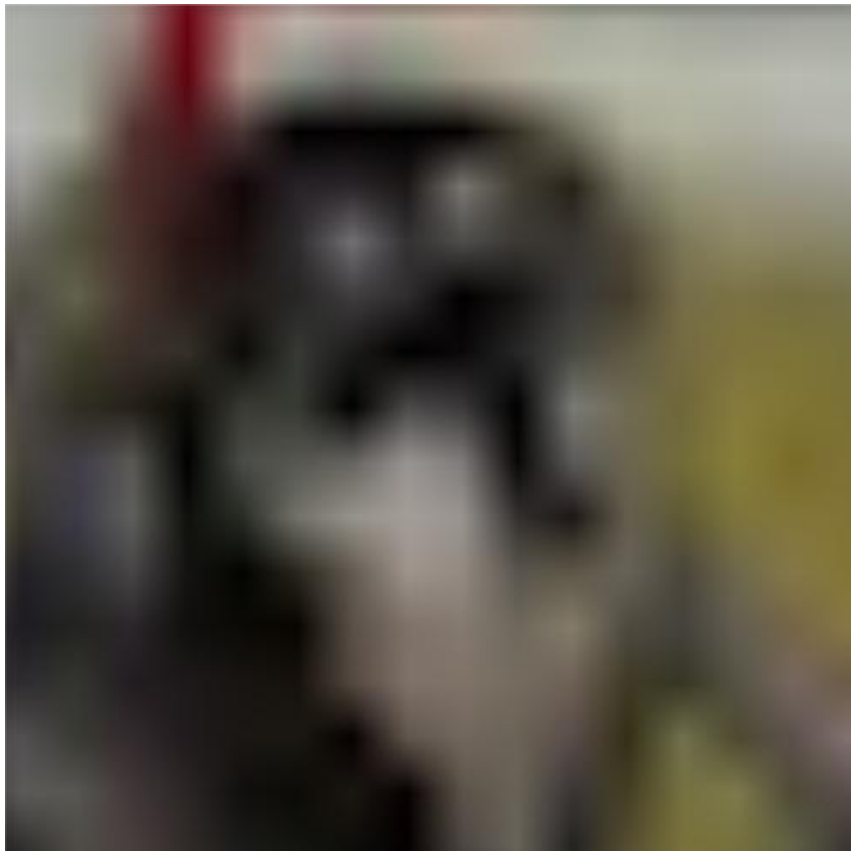
Bilinear Bicubic

Bicubic vs bilinear



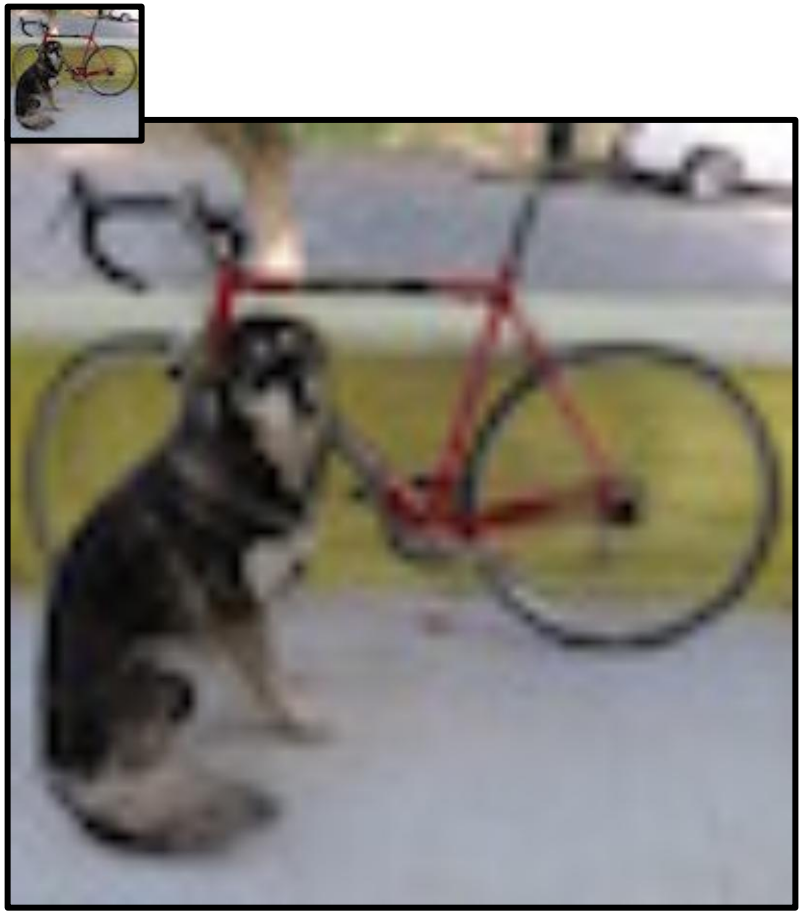
Bicubic vs bilinear





Resize algorithm:

- For each pixel in new image:
  1. Map to old im coordinates
  2. Interpolate value
  3. Set new value in image



What about shrinking?

- NN and Bilinear only look at small area
- Lots of artifacting
- Staircase pattern on diagonal lines
- We'll fix this next class with filters!

So what is this interpolation useful for?

Image resizing!

Say we want to increase the size of an image…

This is a beautiful image of a sunset… it’s just very small…

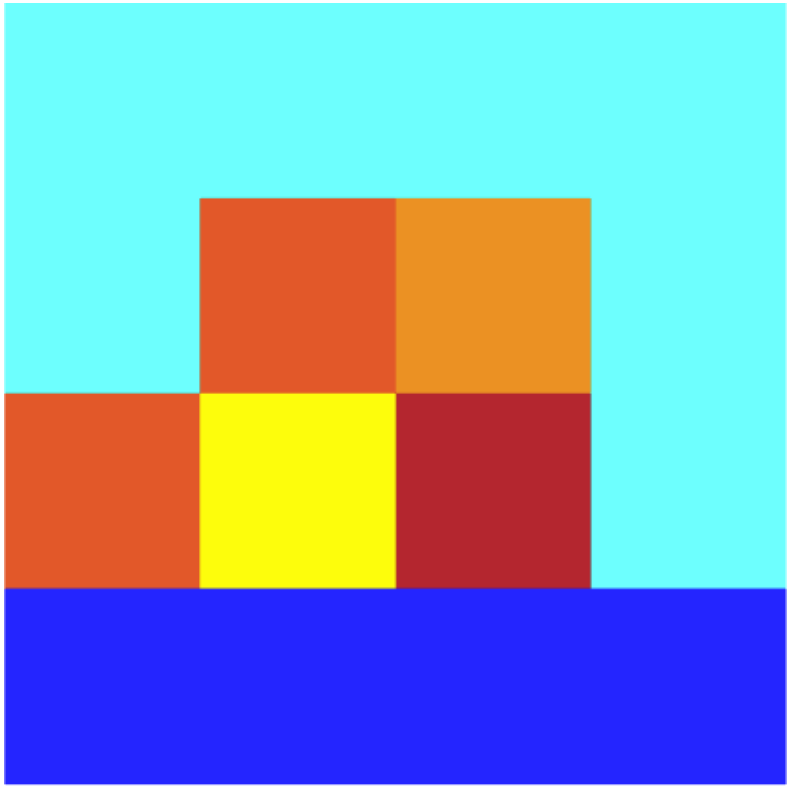
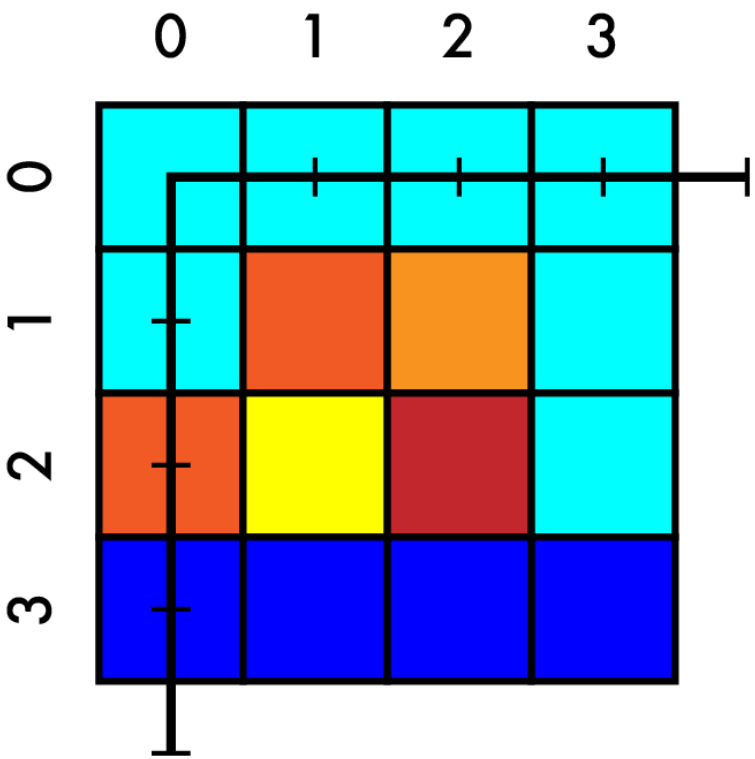


Image resizing!

Say we want to increase the size of an image…

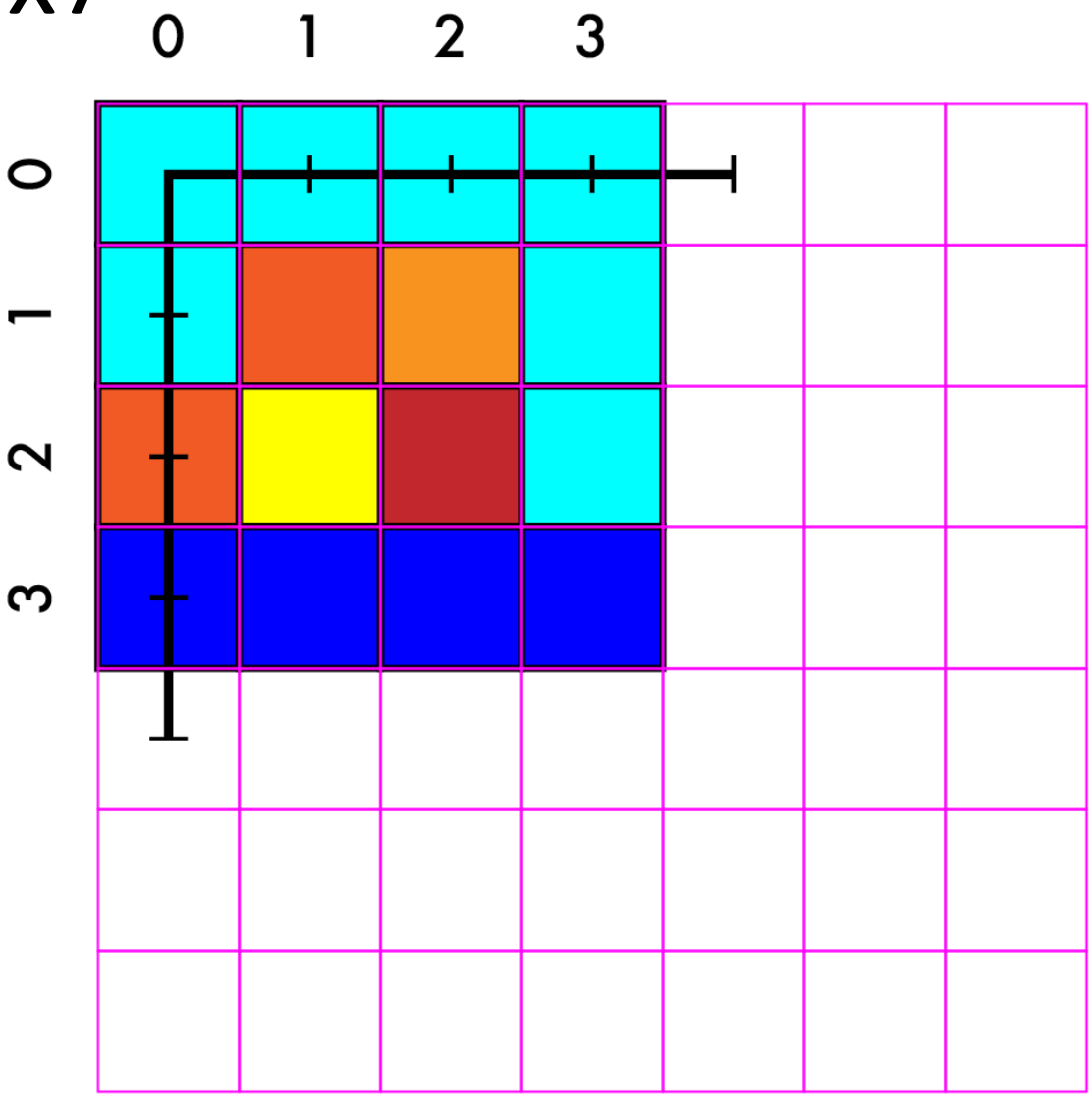
This is a beautiful image of a sunset… it’s just very small…

Say we want to increase size 4x4 -> 7x7



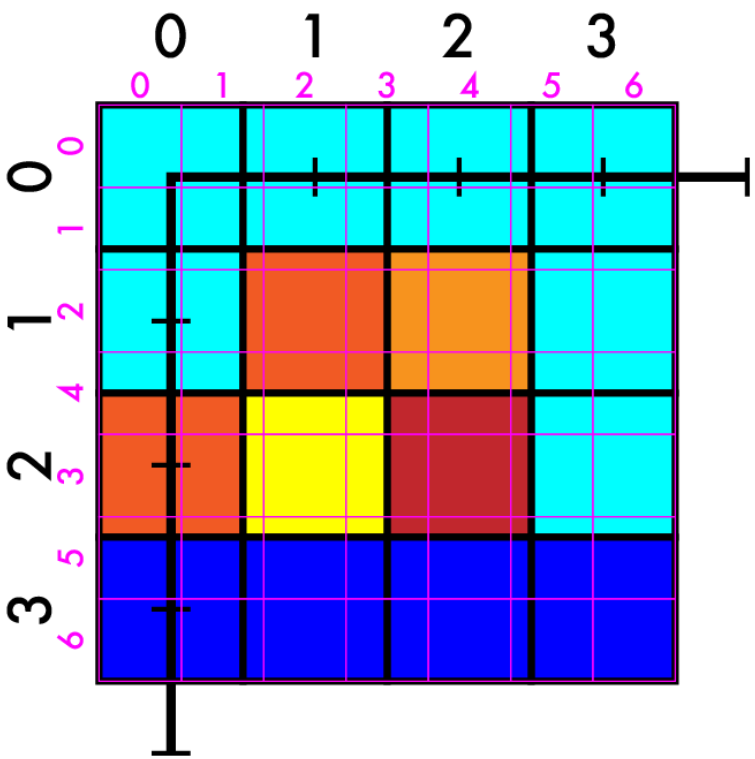
Resize 4x4 -> 7x7

- Create our new image



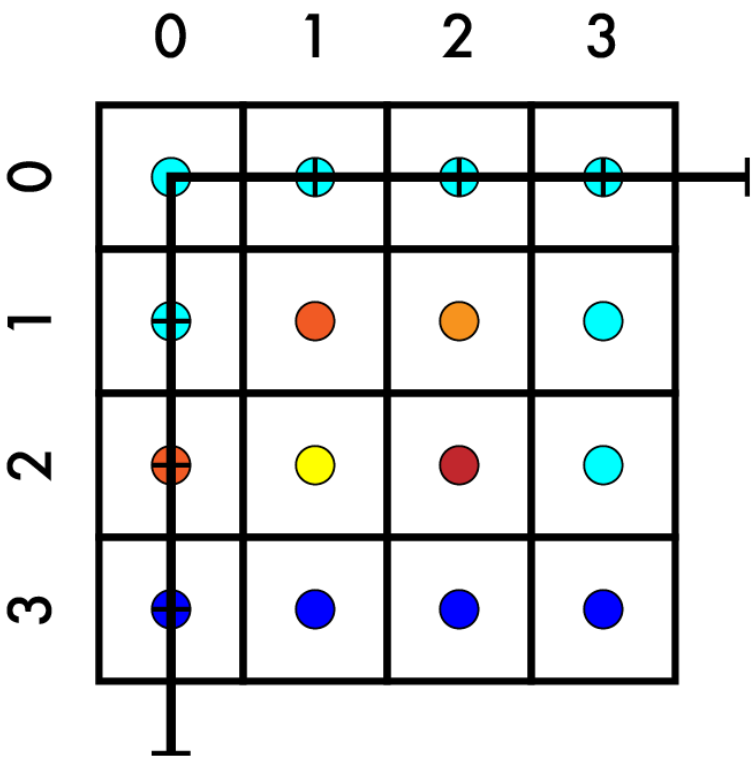
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates



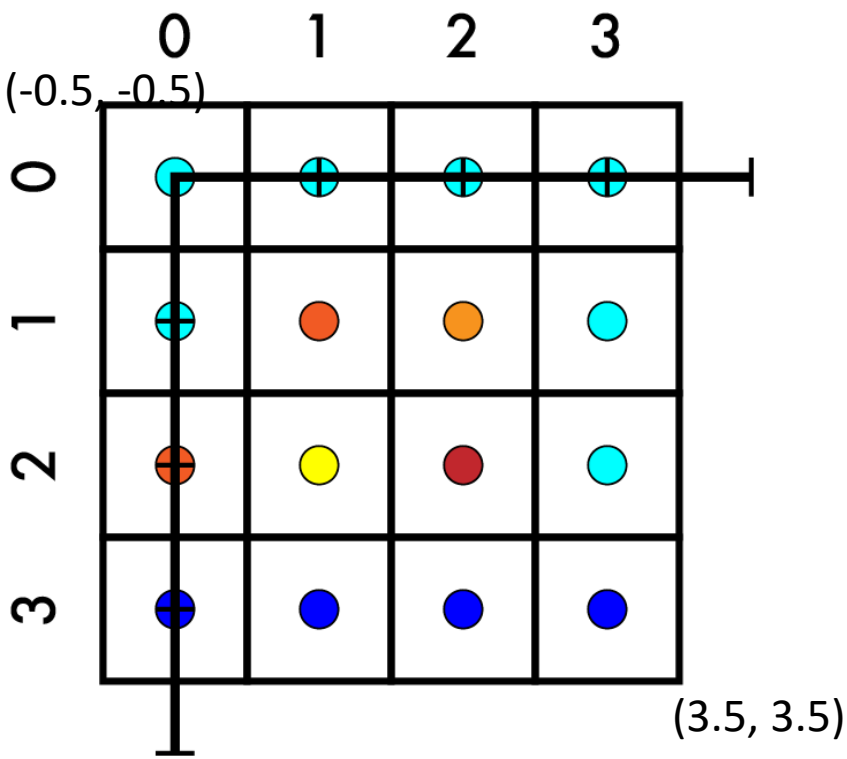
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates



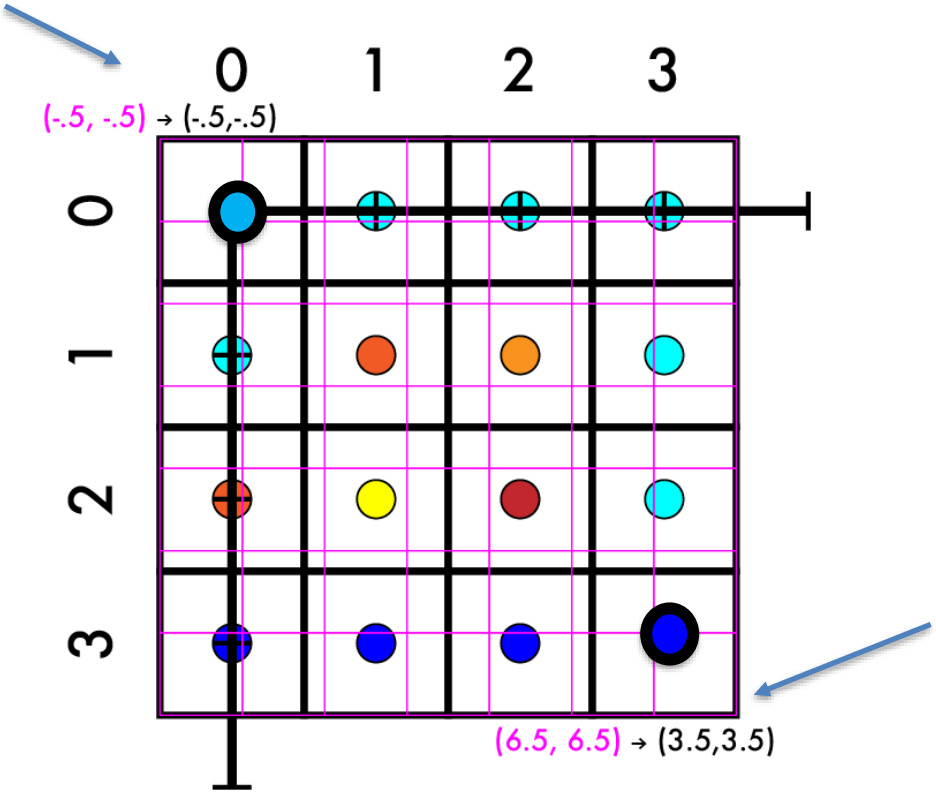
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates



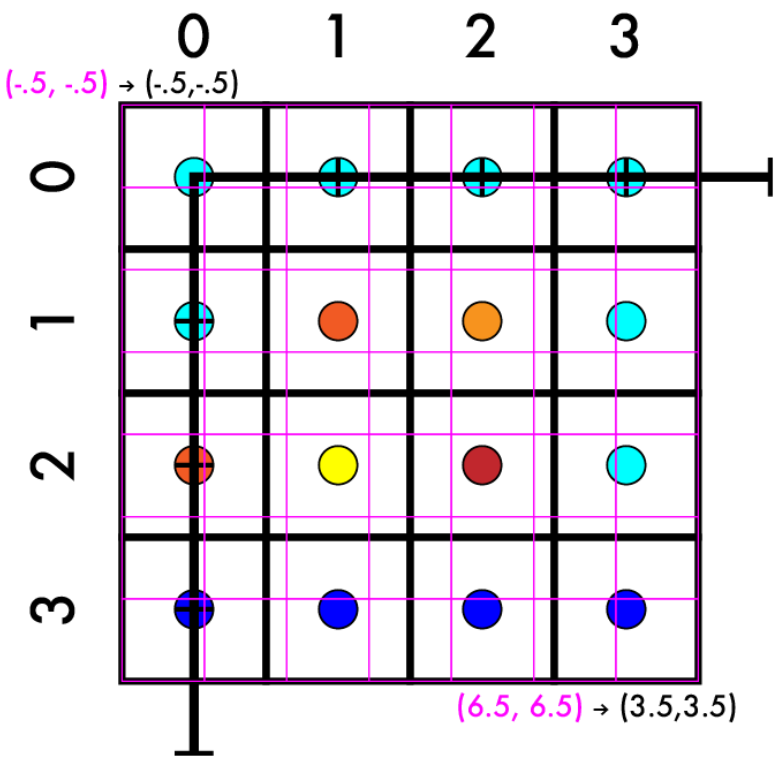
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - System of equations
  - aX + b = Y
  - a*-.5 + b = -.5
  - a*6.5 + b = 3.5



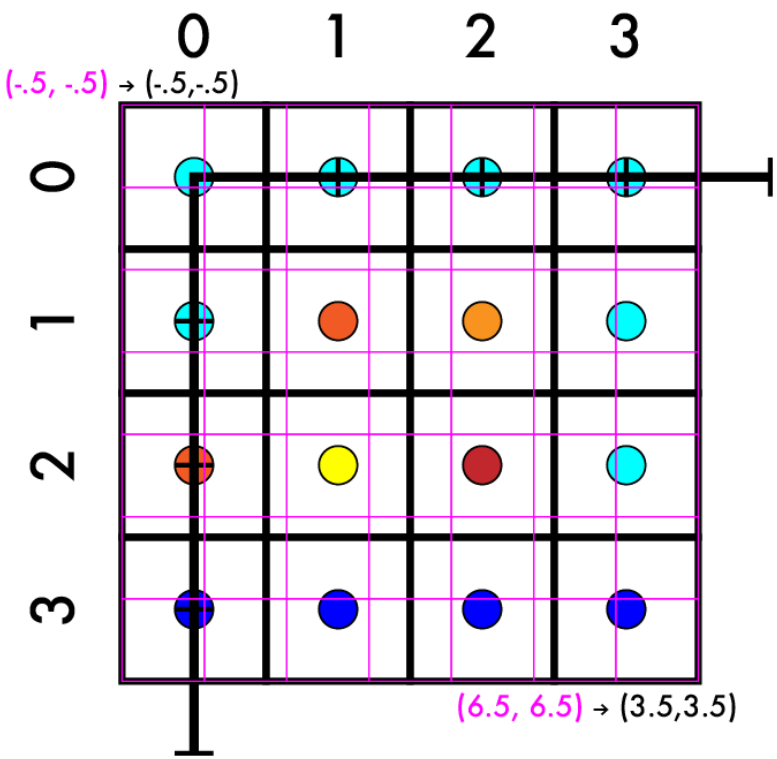
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - System of equations
  - aX + b = Y
  - a*-.5 + b = -.5
  - a*6.5 + b = 3.5
    - a*7 = 4



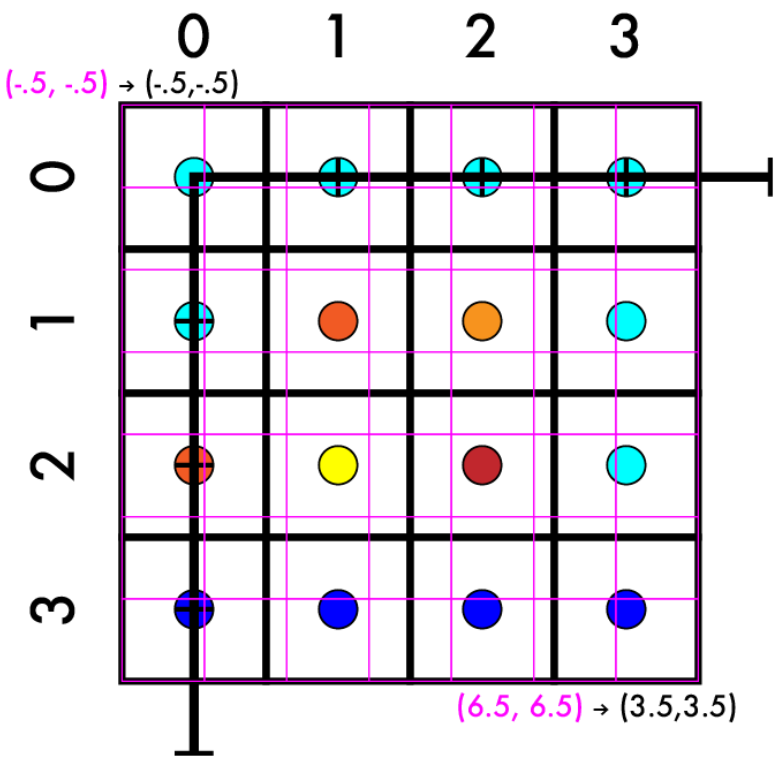
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - System of equations
  - aX + b = Y
  - a*-.5 + b = -.5
  - a*6.5 + b = 3.5
    - a*7 = 4
    - a = 4/7



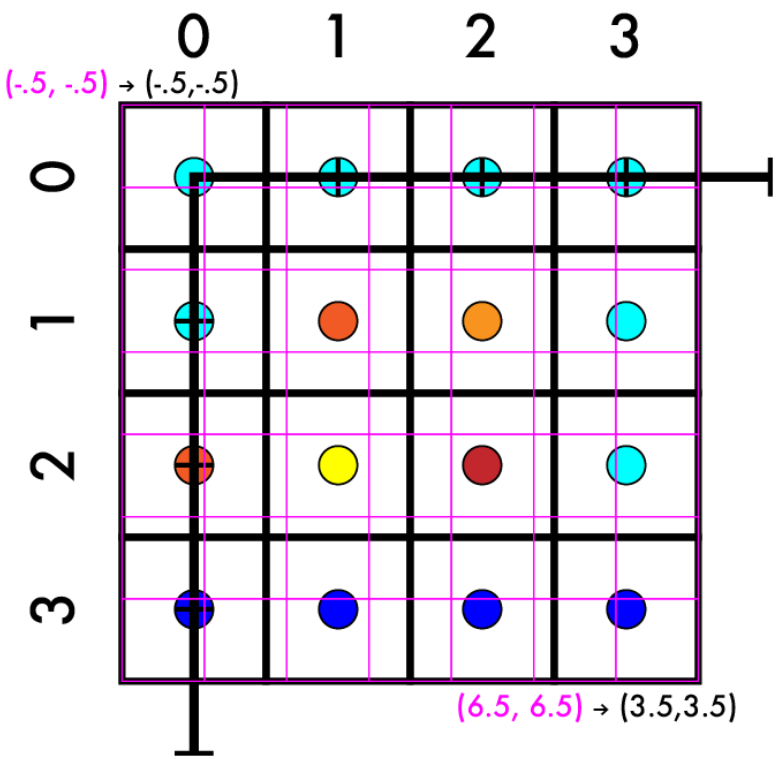
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - System of equations
  - aX + b = Y
  - a*-.5 + b = -.5
  - a*6.5 + b = 3.5
  - a = 4/7



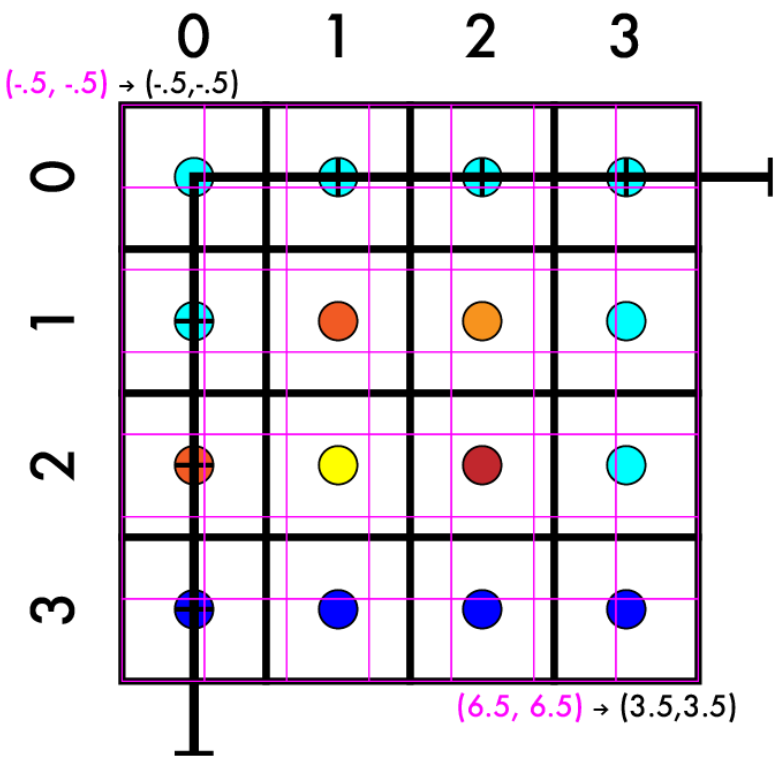
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - System of equations
  - aX + b = Y
  - a*-.5 + b = -.5
  - a*6.5 + b = 3.5
  - a = 4/7
    - a*-.5 + b = -.5



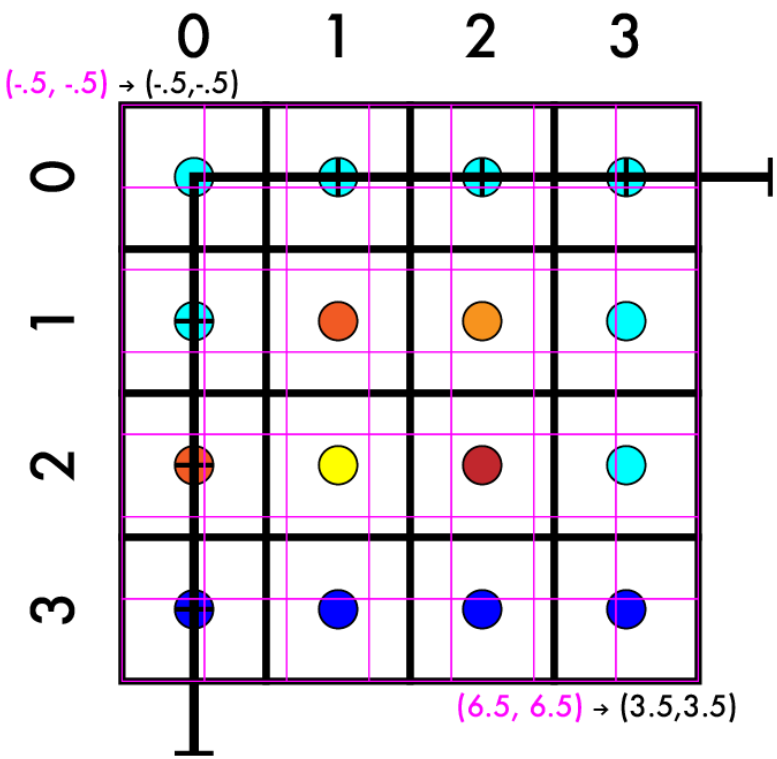
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - System of equations
  - aX + b = Y
  - a*-.5 + b = -.5
  - a*6.5 + b = 3.5
  - a = 4/7
    - a*-.5 + b = -.5
    - 4/7*-1/2 + b = -1/2



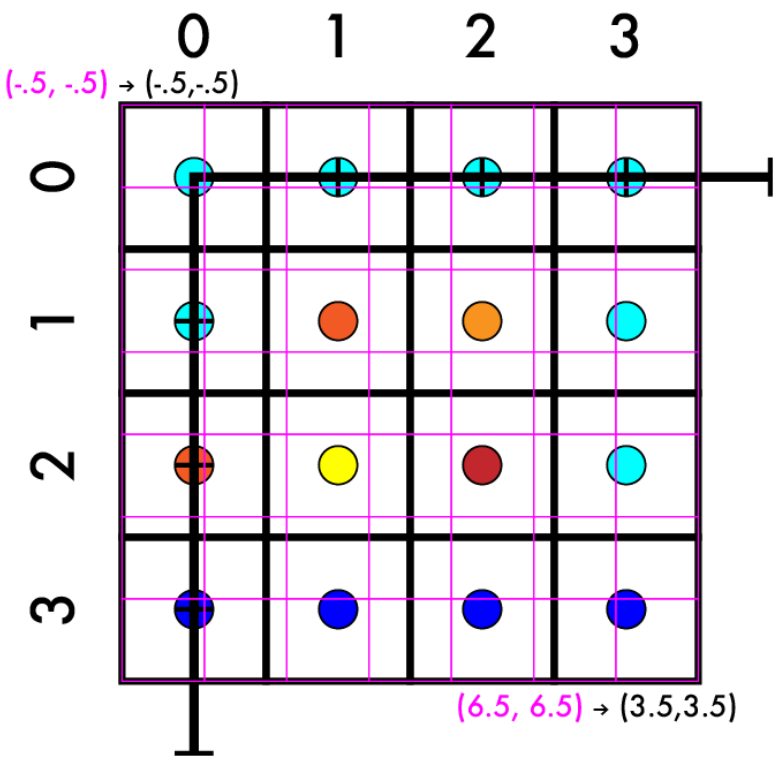
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - System of equations
  - aX + b = Y
  - a*-.5 + b = -.5
  - a*6.5 + b = 3.5
  - a = 4/7
    - a*-.5 + b = -.5
    - 4/7*-1/2 + b = -1/2
    - -4/14 + b = -7/14



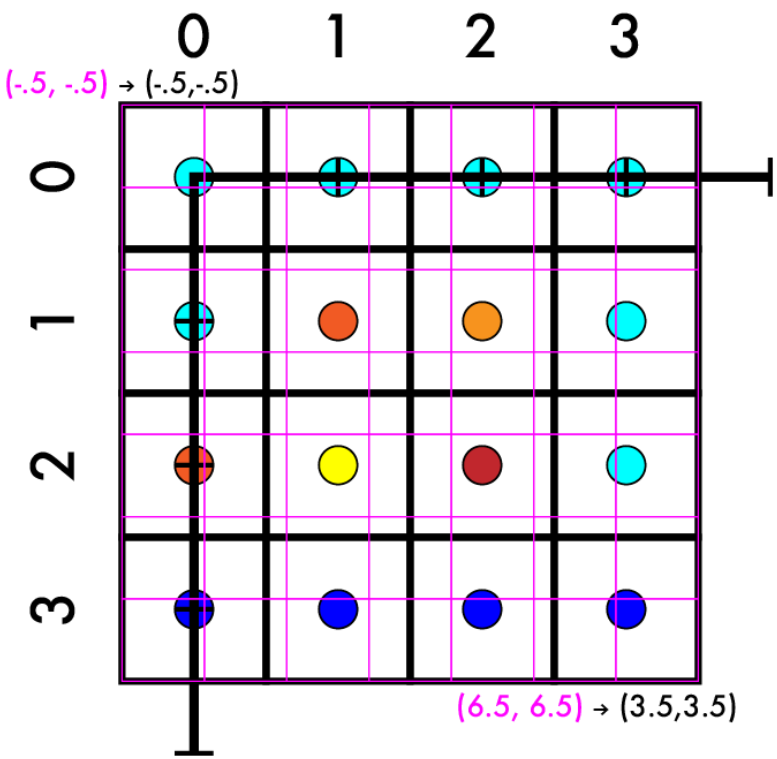
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - System of equations
  - aX + b = Y
  - a*-.5 + b = -.5
  - a*6.5 + b = 3.5
  - a = 4/7
    - a*-.5 + b = -.5
    - 4/7*-1/2 + b = -1/2
    - -4/14 + b = -7/14
    - b = -3/14



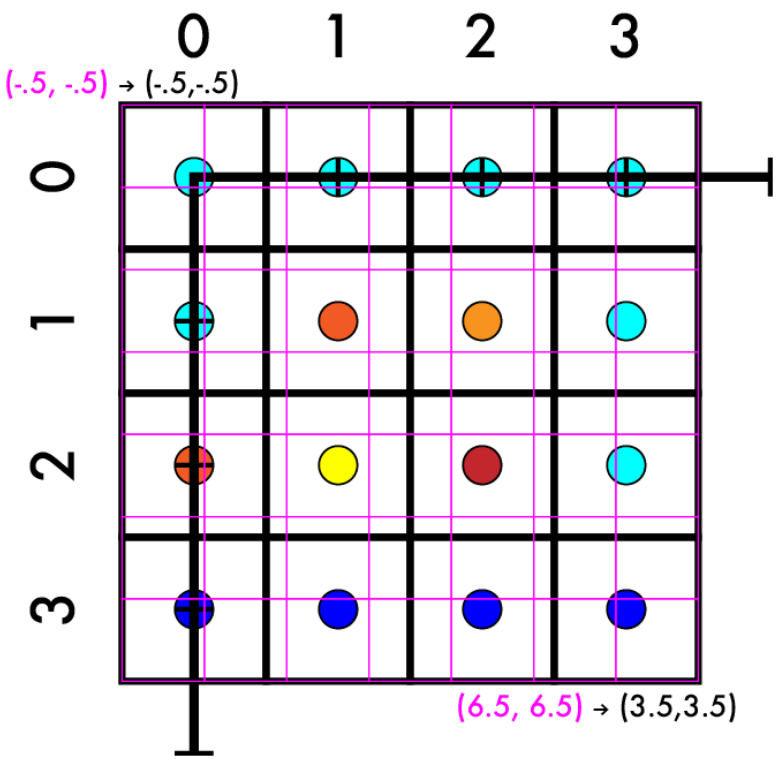
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - System of equations
  - aX + b = Y
  - a*-.5 + b = -.5
  - a*6.5 + b = 3.5
  - a = 4/7
  - b = -3/14
- So, we can start with any coordinate X of the big (new) image and use a and b to get Y on the smaller (old) image.



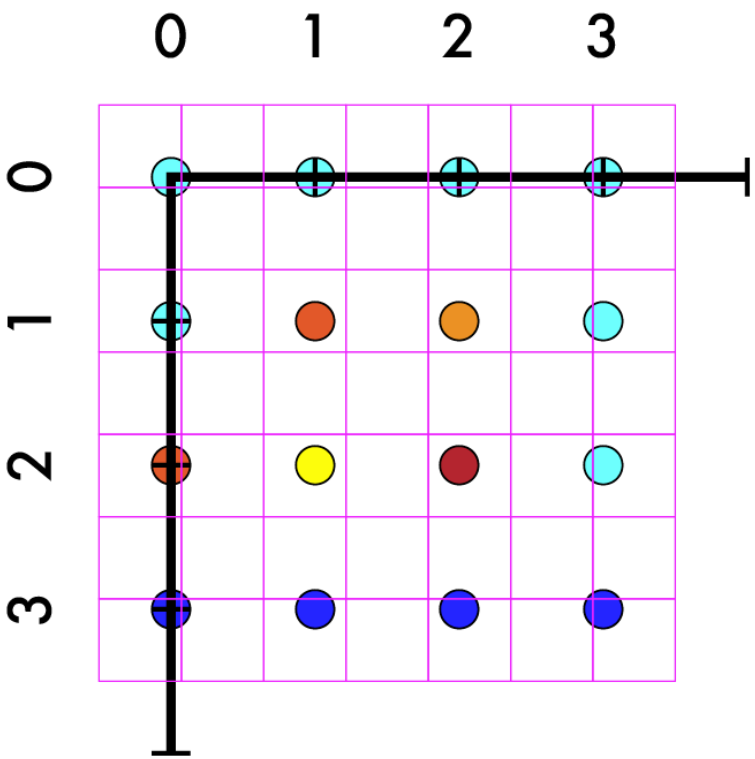
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - 4/7 X - 3/14 = Y



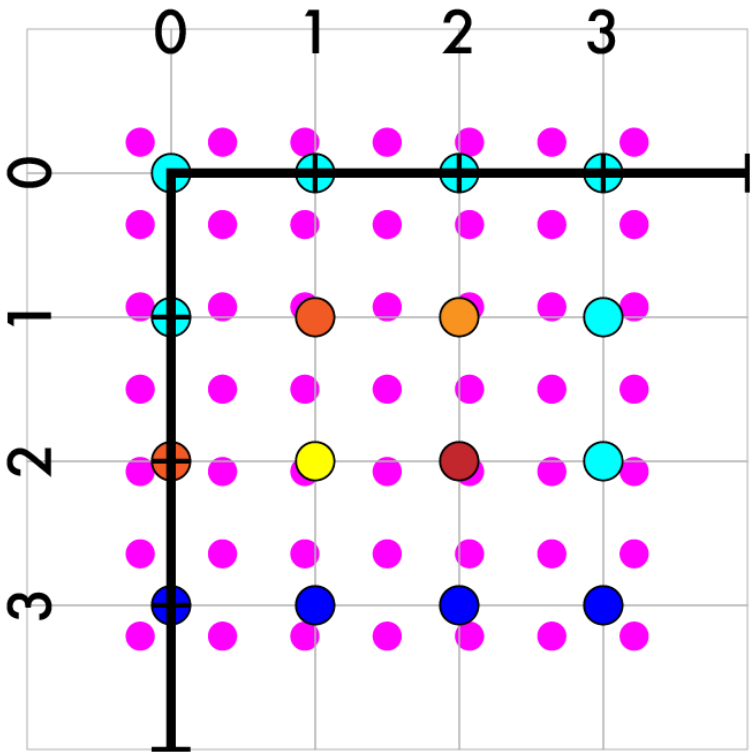
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - 4/7 X - 3/14 = Y



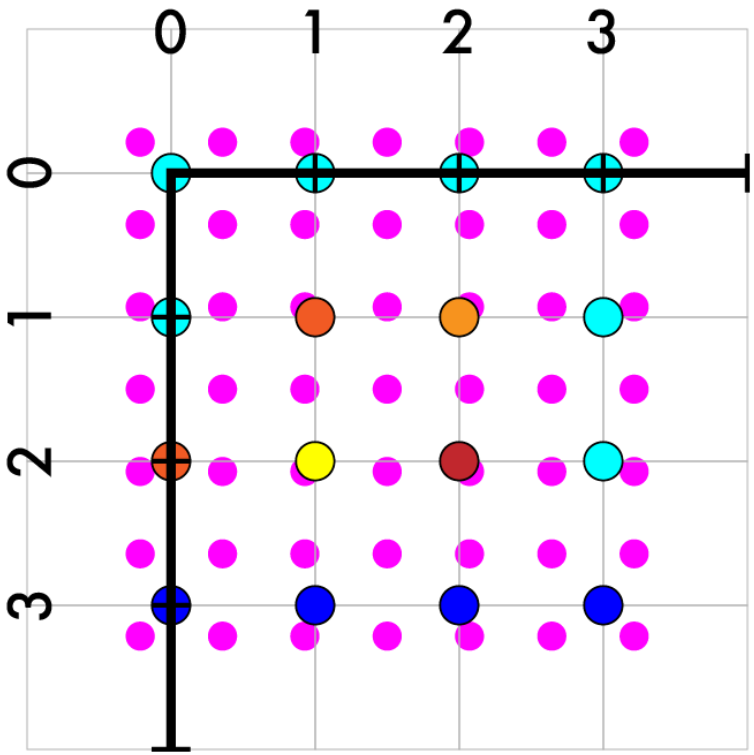
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - 4/7 X - 3/14 = Y
- Iterate over new pts



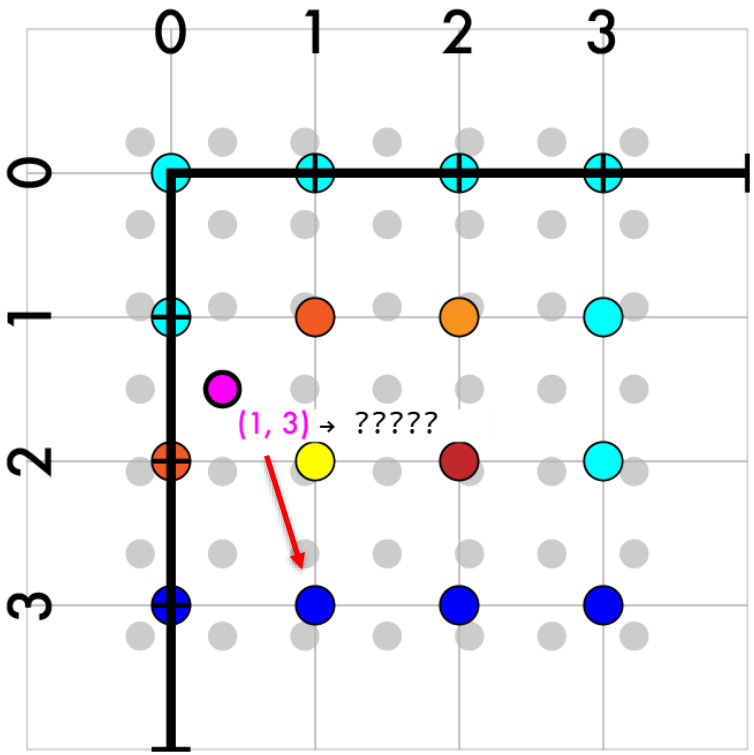
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - 4/7 X - 3/14 = Y
- Iterate over new pts
  - Map to old coords (Y is old)



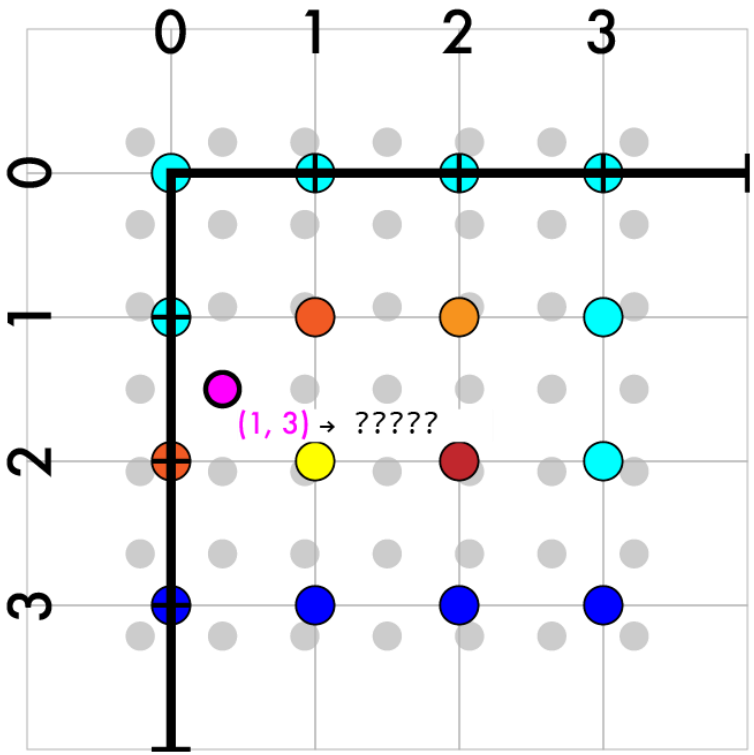
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - 4/7 X - 3/14 = Y
- Iterate over new pts
  - Map to old coords (Y is old)
  - (1, 3)



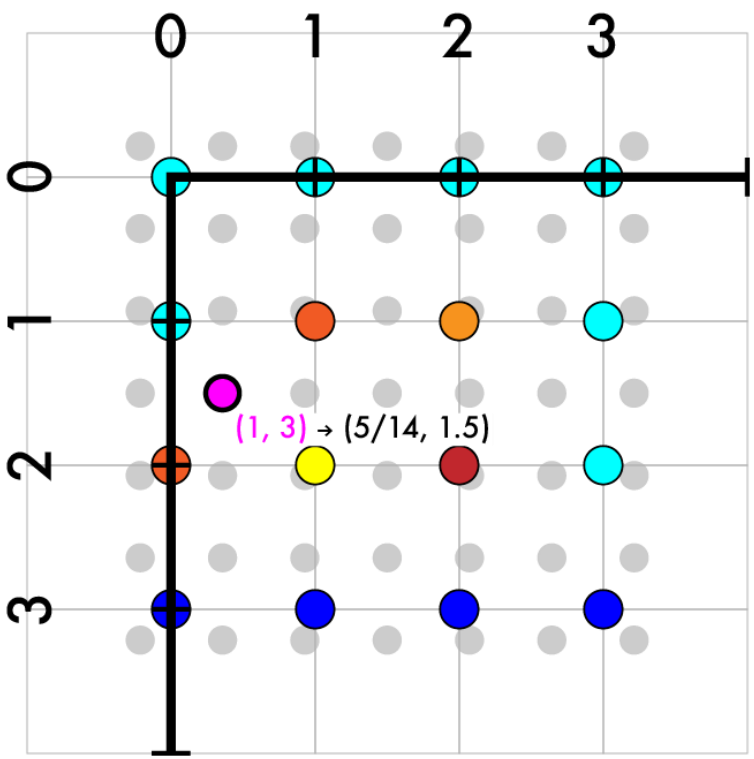
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - 4/7 X - 3/14 = Y
- Iterate over new pts
  - Map to old coords
  - (1, 3)
  - 4/7*1 - 3/14
  - 4/7*3 - 3/14



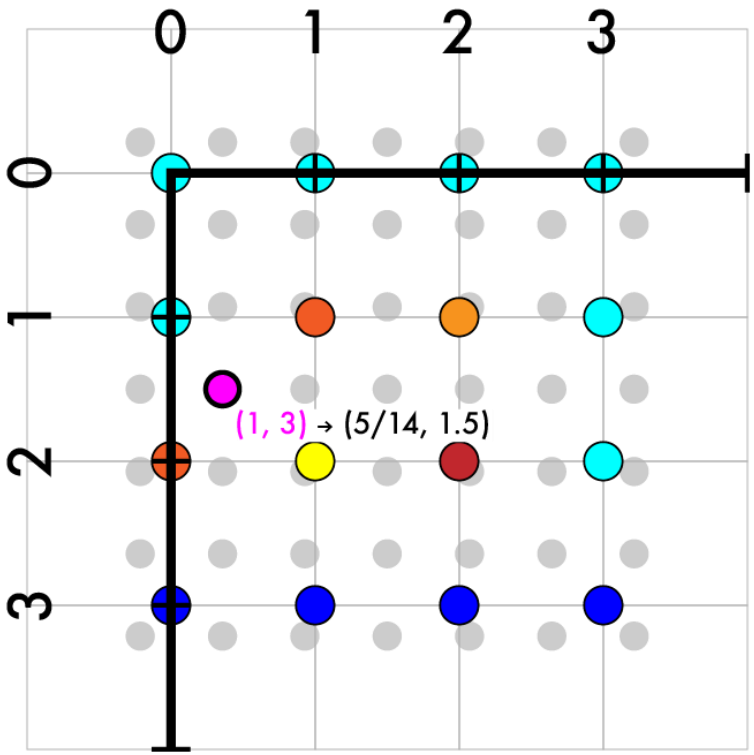
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - 4/7 X - 3/14 = Y
- Iterate over new pts
  - Map to old coords
  - (1, 3)
  - 4/7*1 - 3/14
  - 4/7*3 - 3/14
  - (5/14, 21/14)



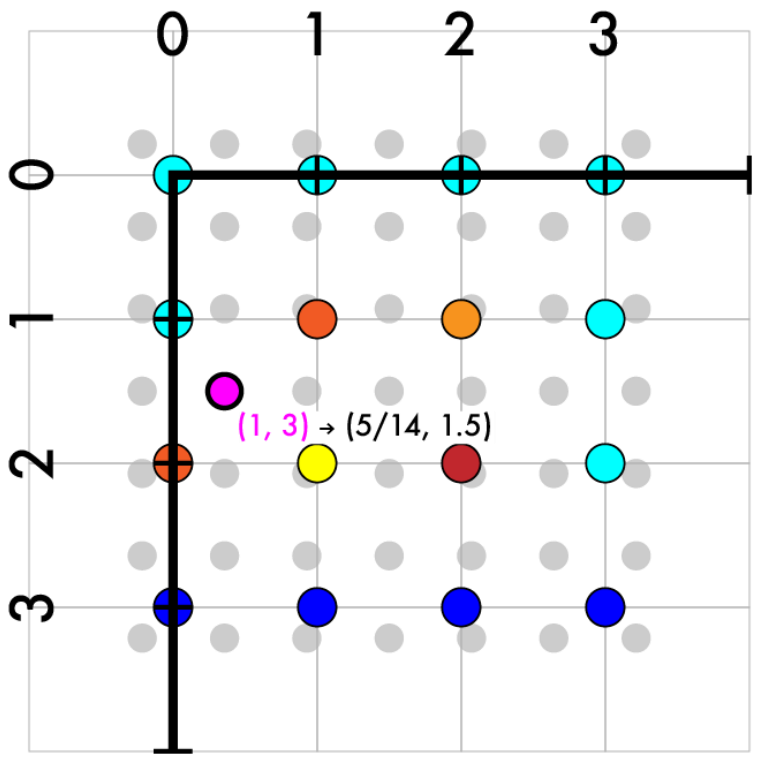
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - 4/7 X - 3/14 = Y
- Iterate over new pts
  - Map to old coords
  - (1, 3) -> (5/14, 21/14)



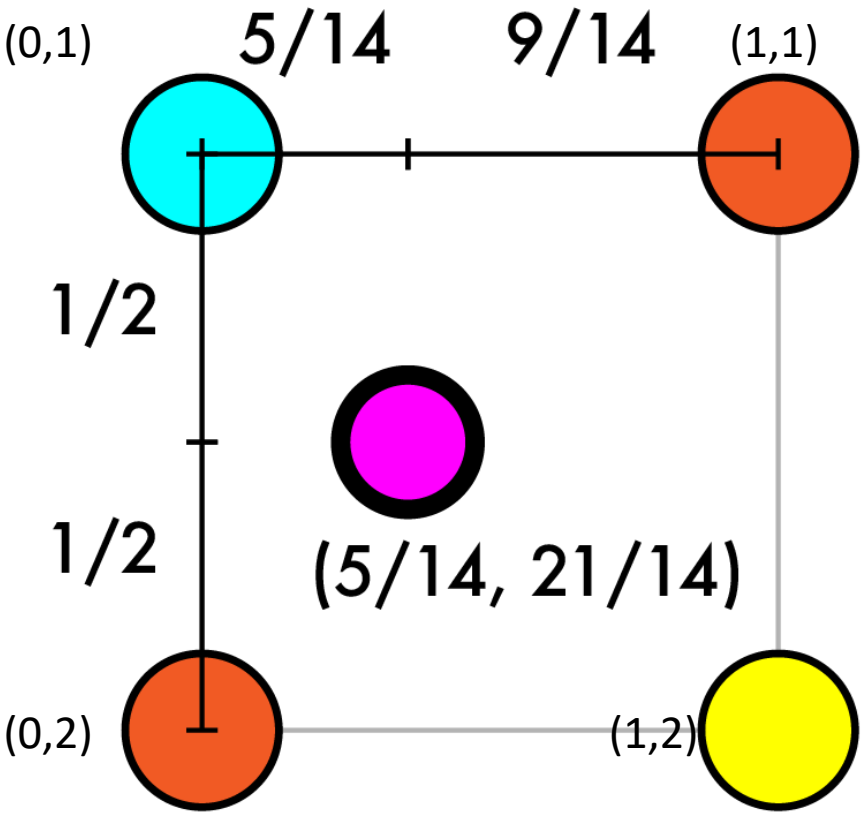
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - 4/7 X - 3/14 = Y
- Iterate over new pts
  - Map to old coords
  - (1, 3) -> (5/14, 21/14)
  - Interpolate old values



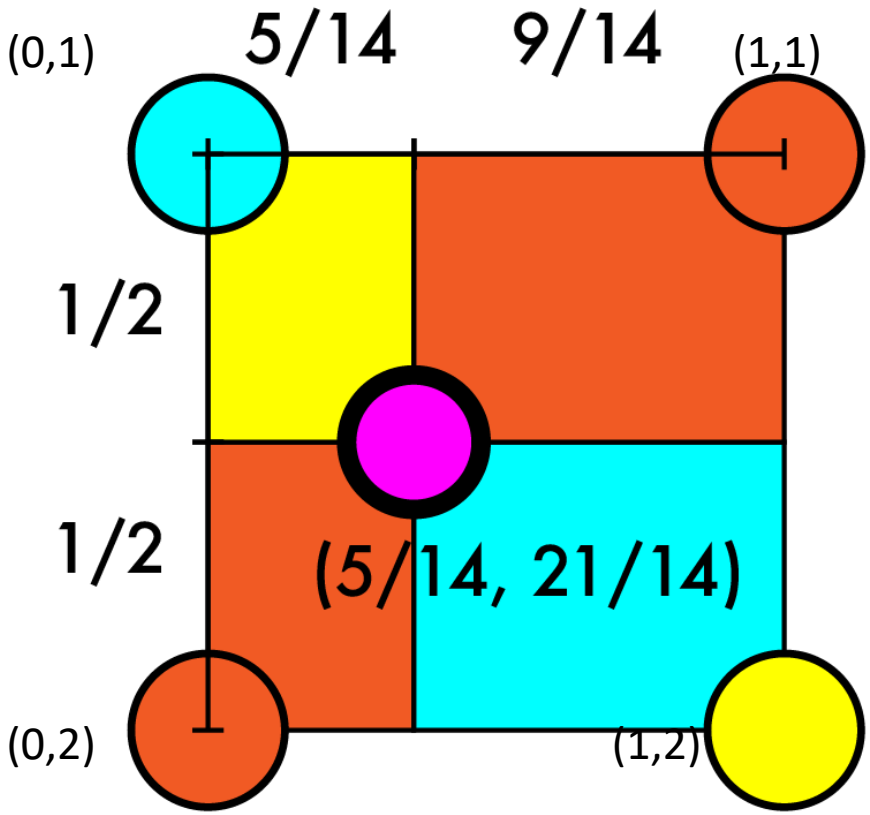
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - 4/7 X - 3/14 = Y
- Iterate over new pts
  - Map to old coords
  - (1, 3) -> (5/14, 21/14)
  - Interpolate old values



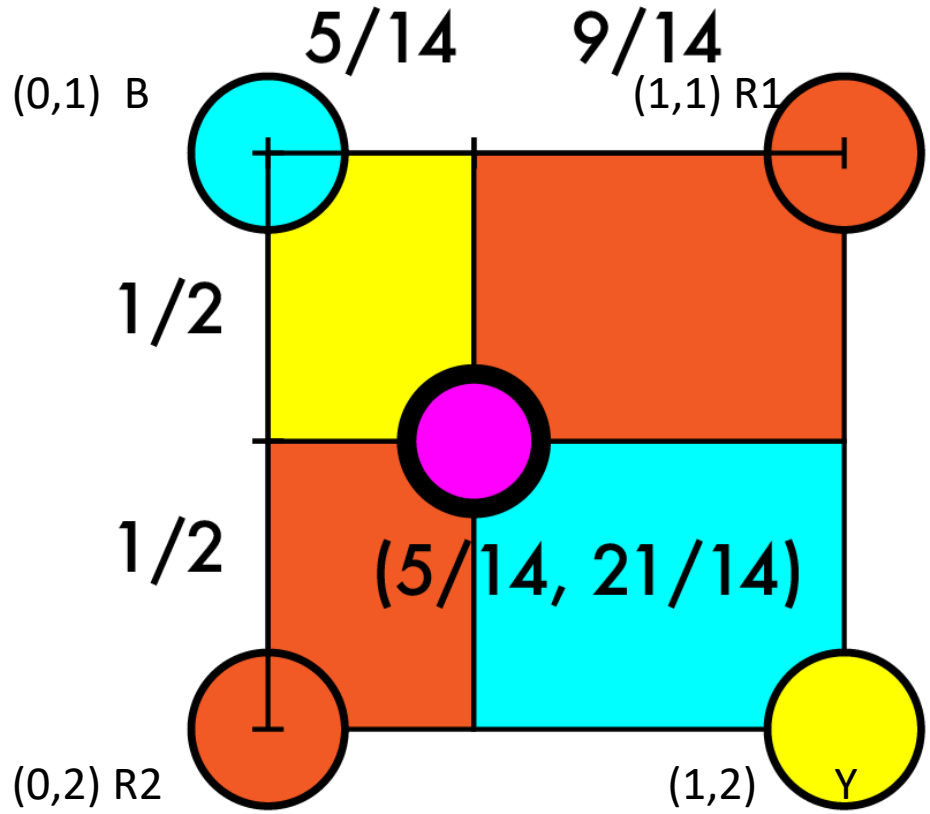
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - 4/7 X - 3/14 = Y
- Iterate over new pts
  - Map to old coords
  - (1, 3) -> (5/14, 21/14)
  - Interpolate old values
    - Size of opposite rects



Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - 4/7 X - 3/14 = Y
- Iterate over new pts
  - Map to old coords
  - (1, 3) -> (5/14, 21/14)
  - Interpolate old values
    - Yar = (1/2)(5/14)
    - Bar = (1/2)(9/14)
    - R1ar = (1/2)(5/14)
    - R2ar = (1/2)(9/14)

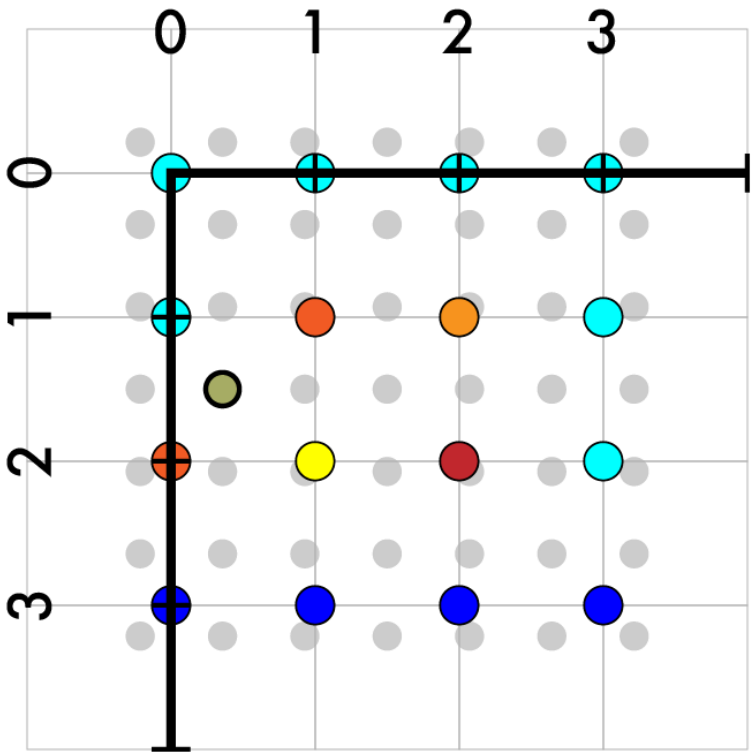


V = Yval*Yar+Bval*Var+R1val*R1ar+R2val*R2ar

- For each channel c, put the interpolated value from that channel in position (1,3,c).

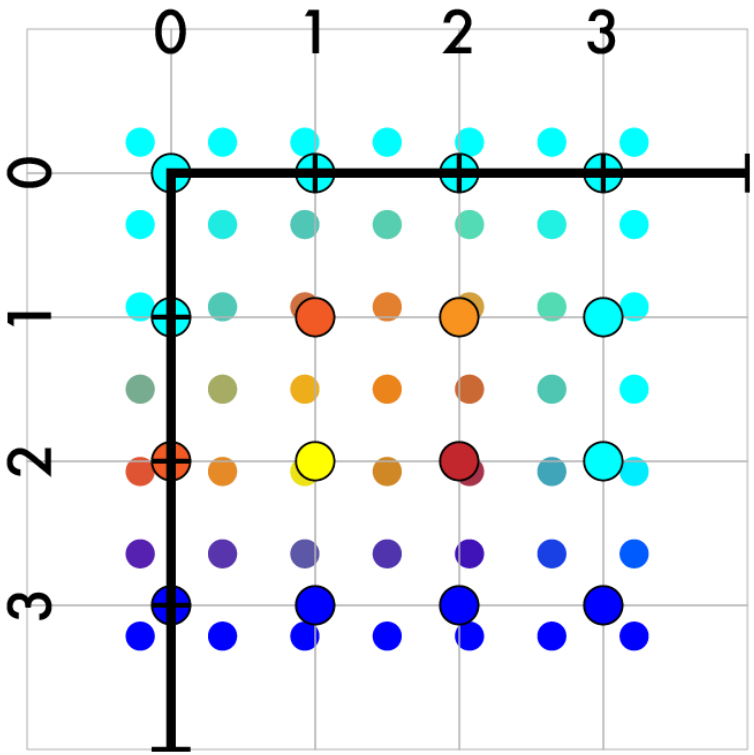
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - 4/7 X - 3/14 = Y
- Iterate over new pts
  - Map to old coords
  - (1, 3) -> (5/14, 21/14)
  - Interpolate old values



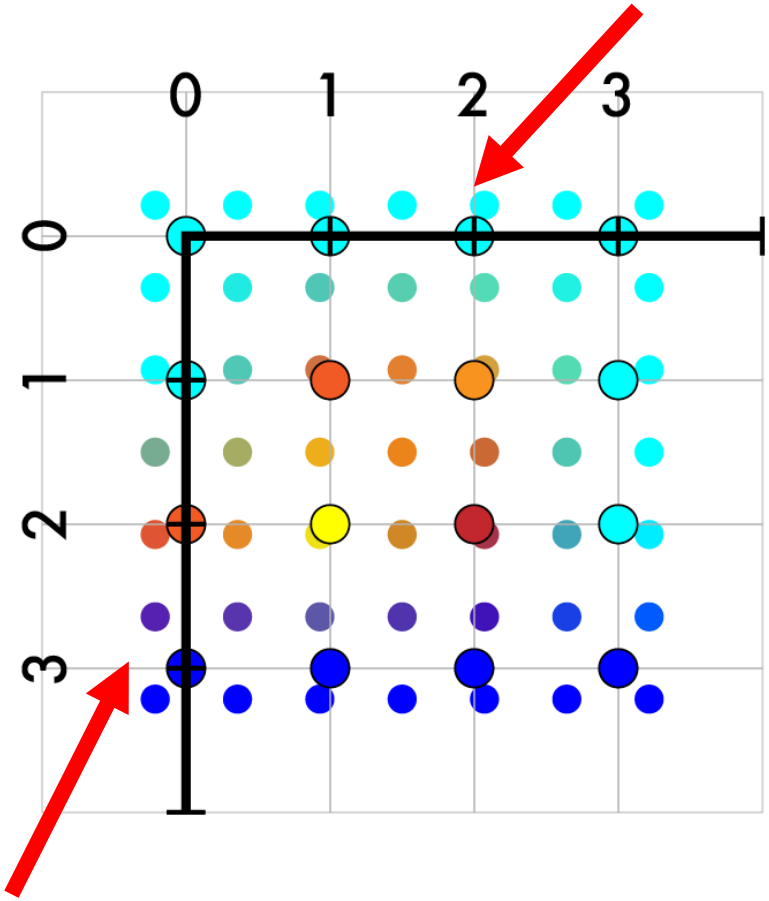
Resize 4x4 -> 7x7

- Create our new image results
- Match up coordinates
  - 4/7 X - 3/14 = Y
- Iterate over new pts
  - Map to old coords
  - (1, 3) -> (5/14, 21/14)
  - Interpolate old values



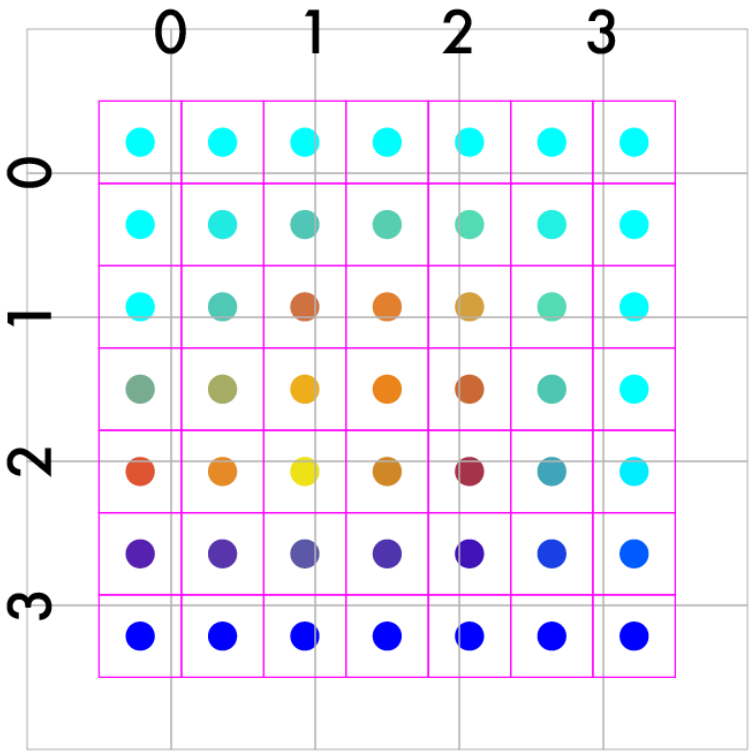
Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - 4/7 X - 3/14 = Y
- Iterate over new pts
  - Map to old coords
  - (1, 3) -> (5/14, 21/14)
  - Interpolate old values
- Fill in the rest
  - On outer edges use padding!

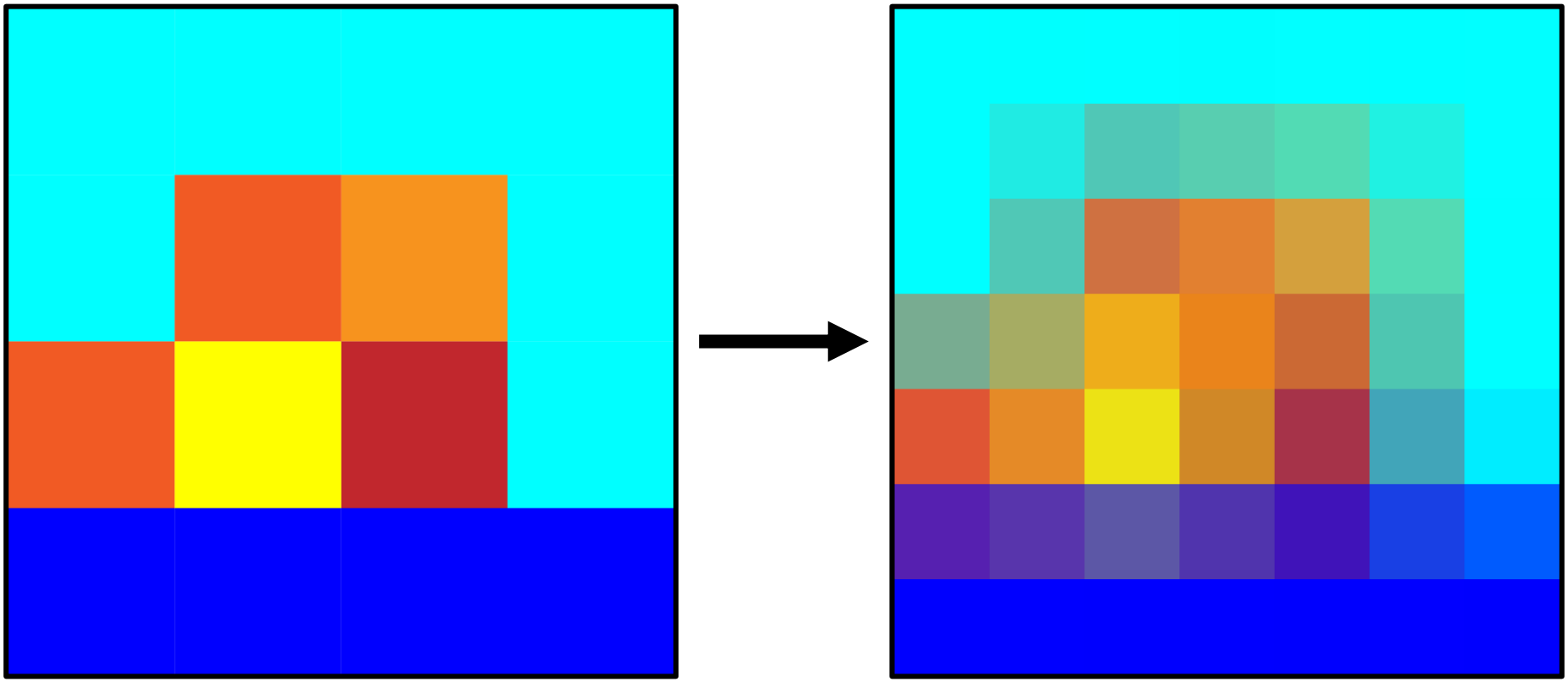


Resize 4x4 -> 7x7

- Create our new image
- Match up coordinates
  - 4/7 X - 3/14 = Y
- Iterate over new pts
  - Map to old coords
  - (1, 3) -> (5/14, 21/14)
  - Interpolate old values
- Final result 7 x 7



We did it!



Let’s do something interesting already!!

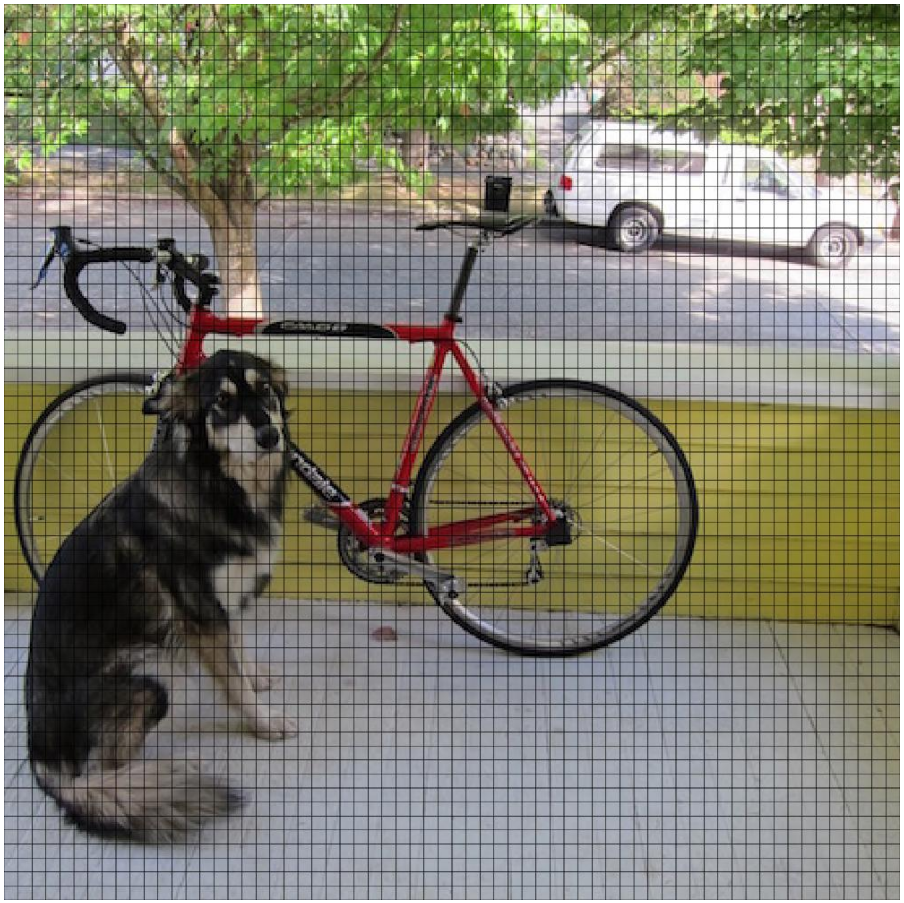
Want to make image smaller

448x448 -> 64x64

448x448 -> 64x64

448x448 -> 64x64

448x448 -> 64x64



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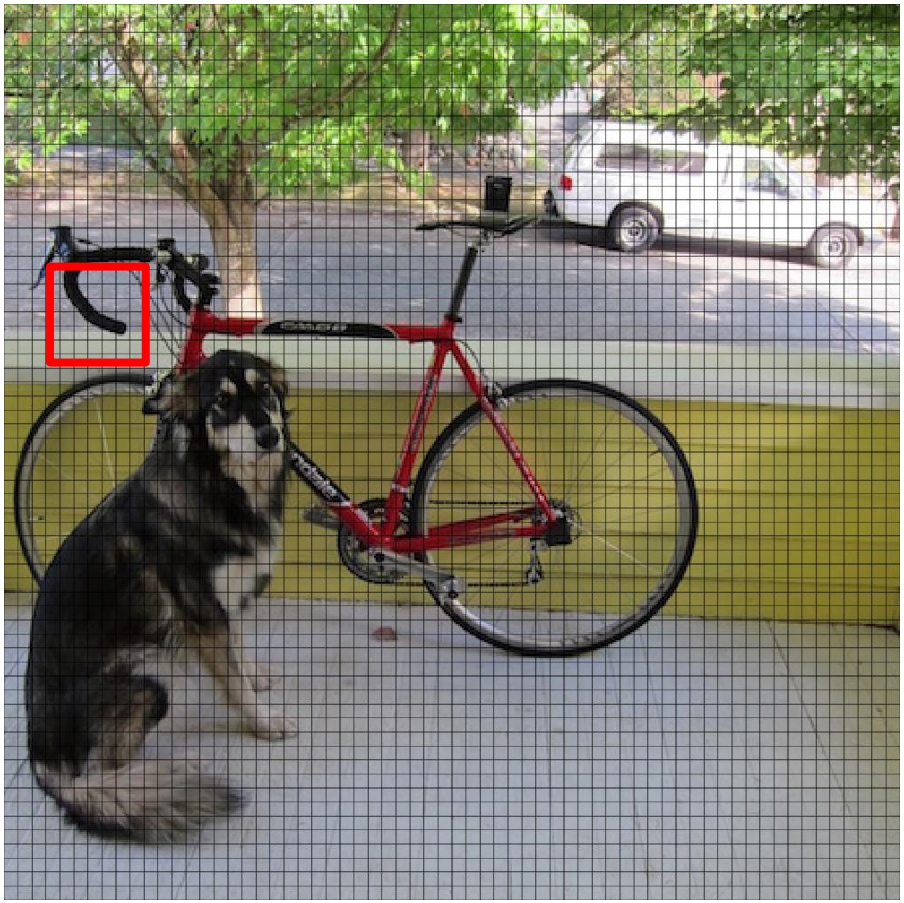

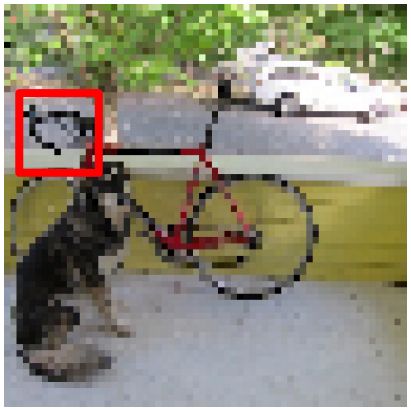

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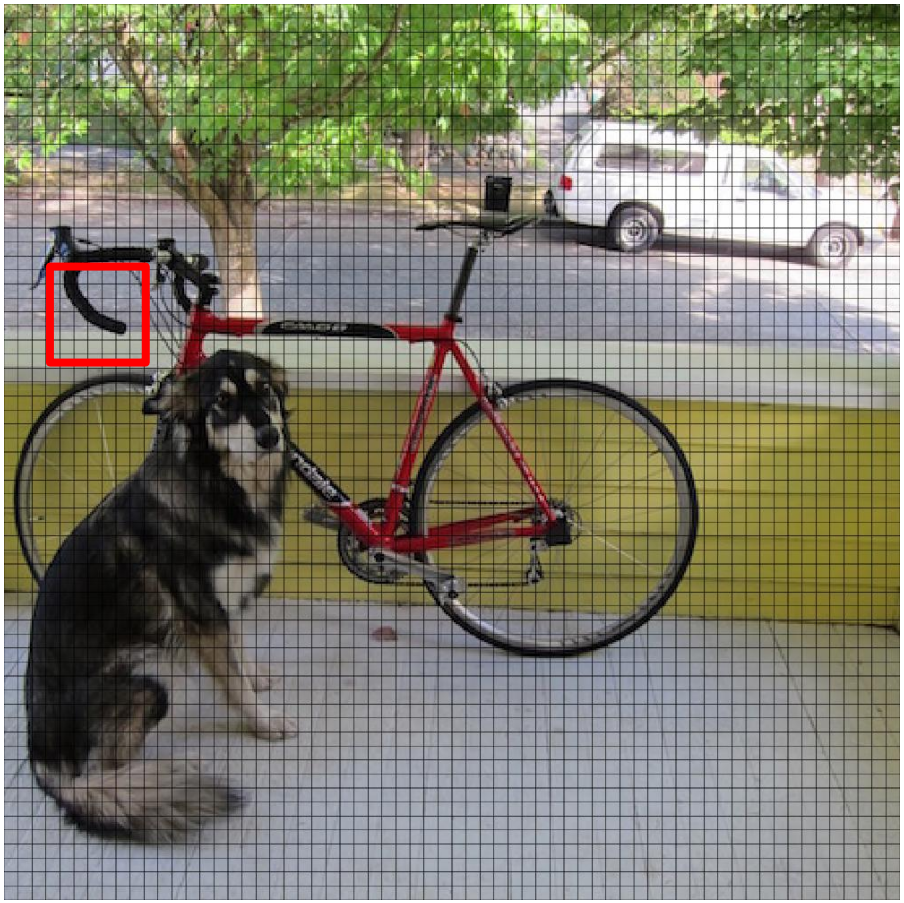

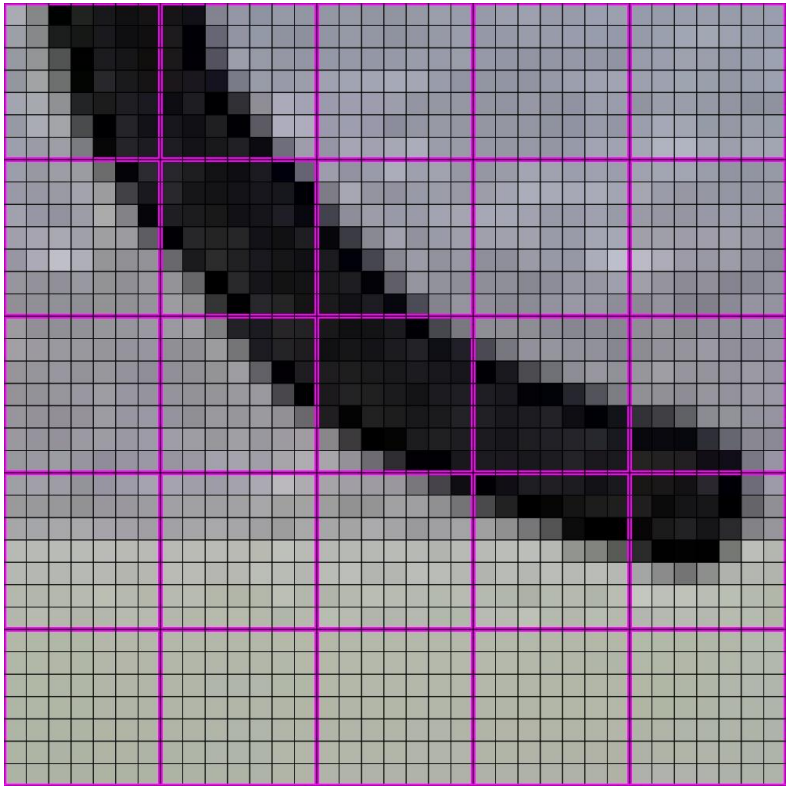

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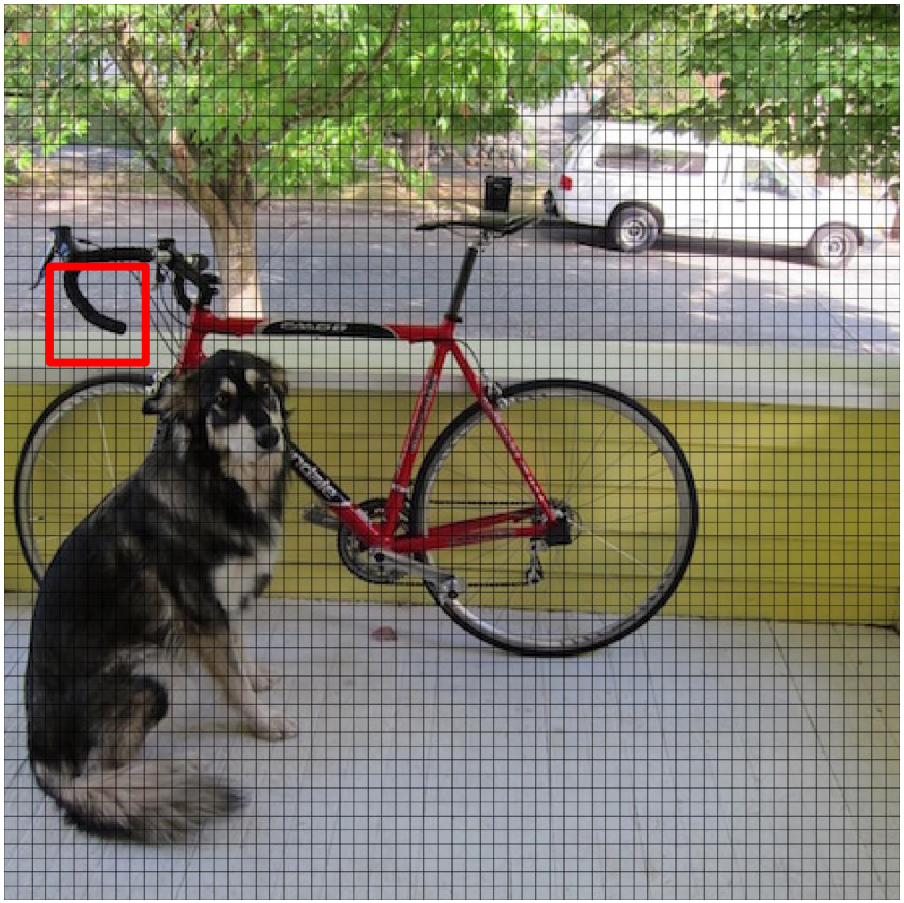

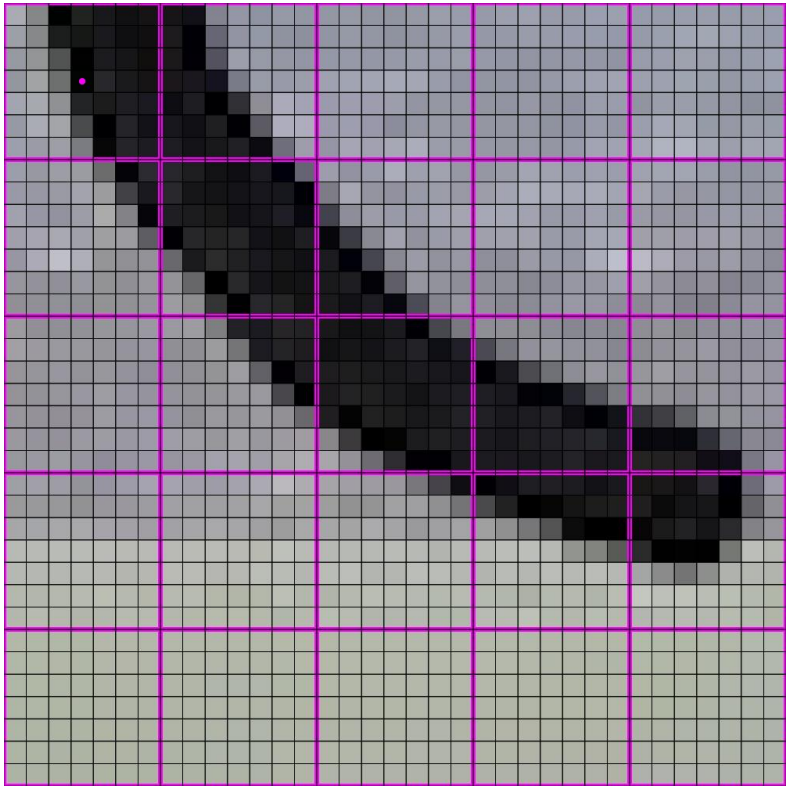

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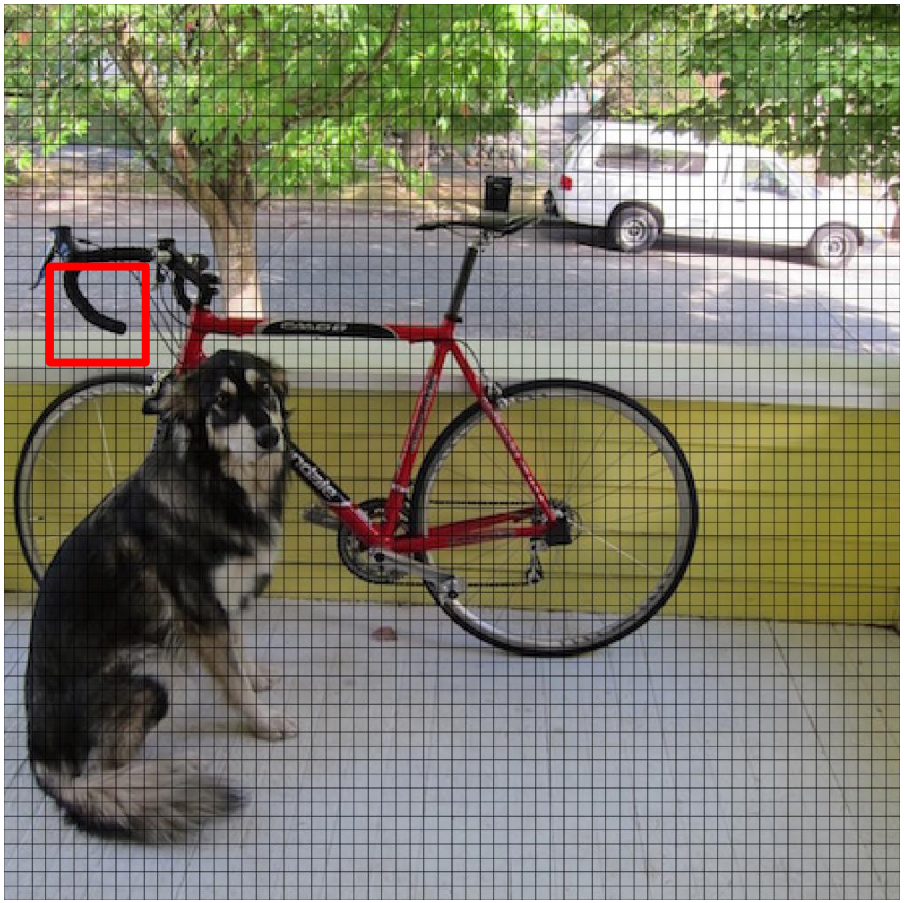

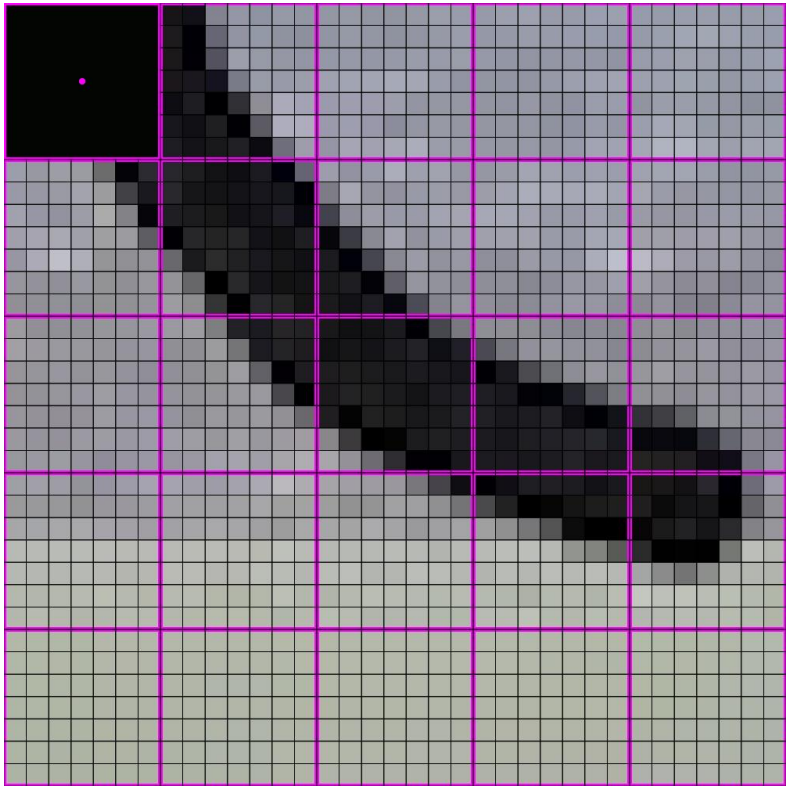

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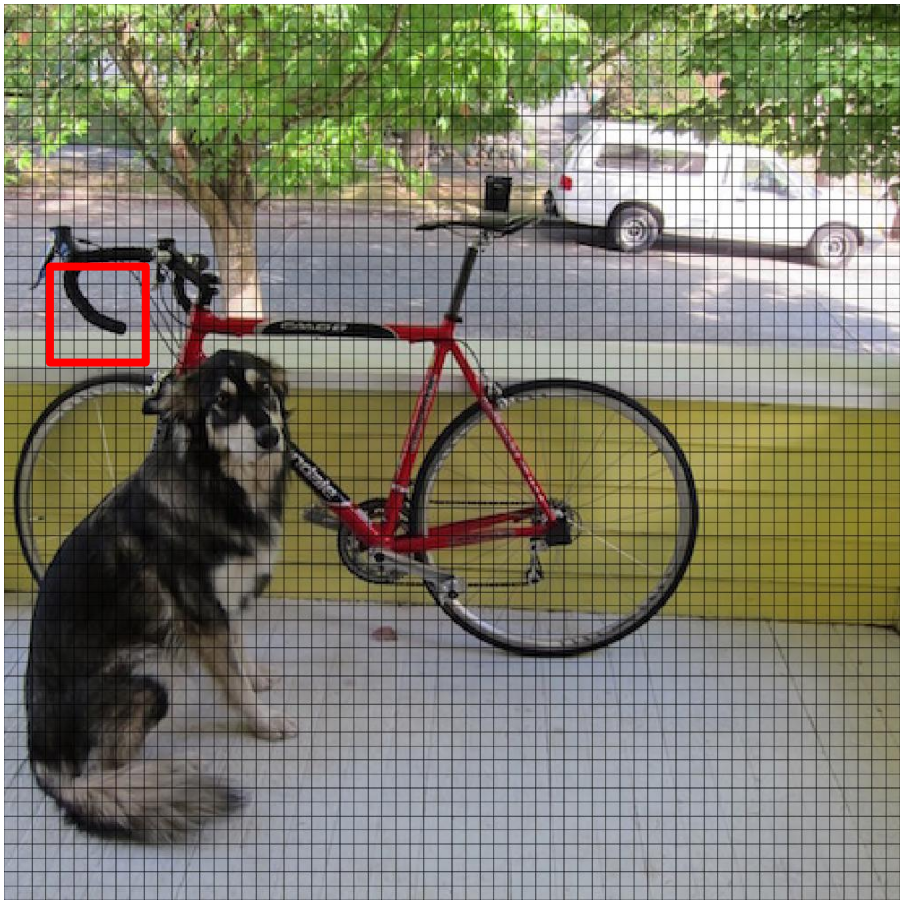

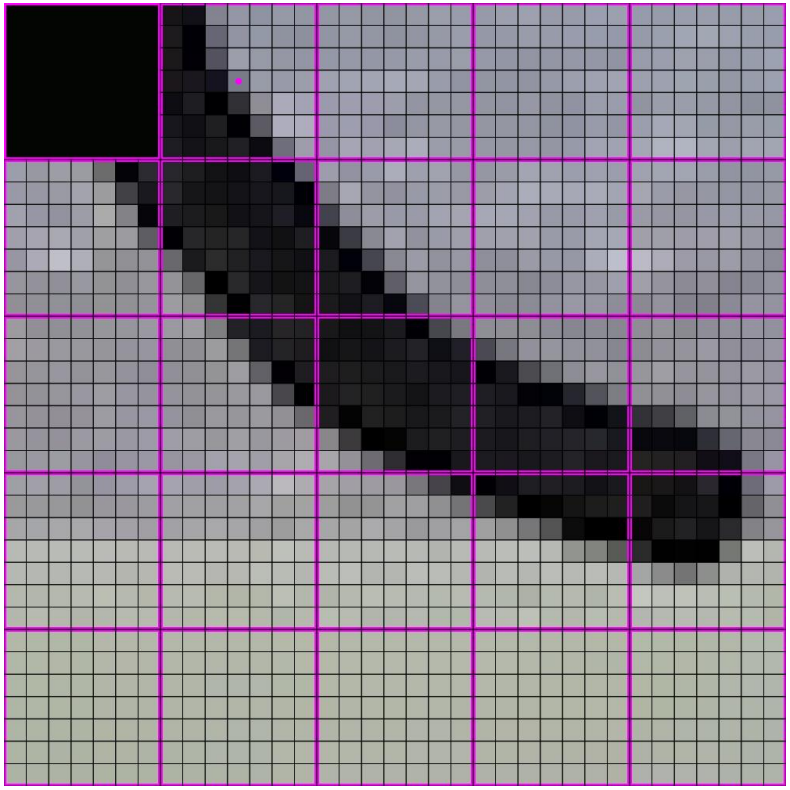

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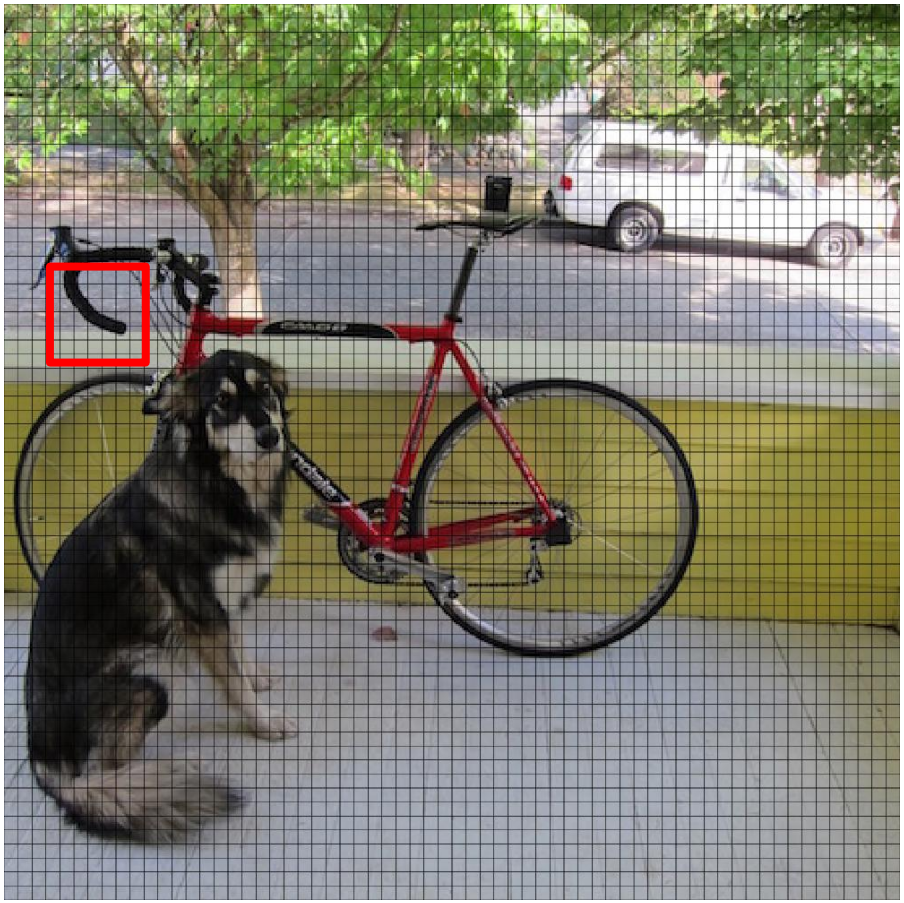

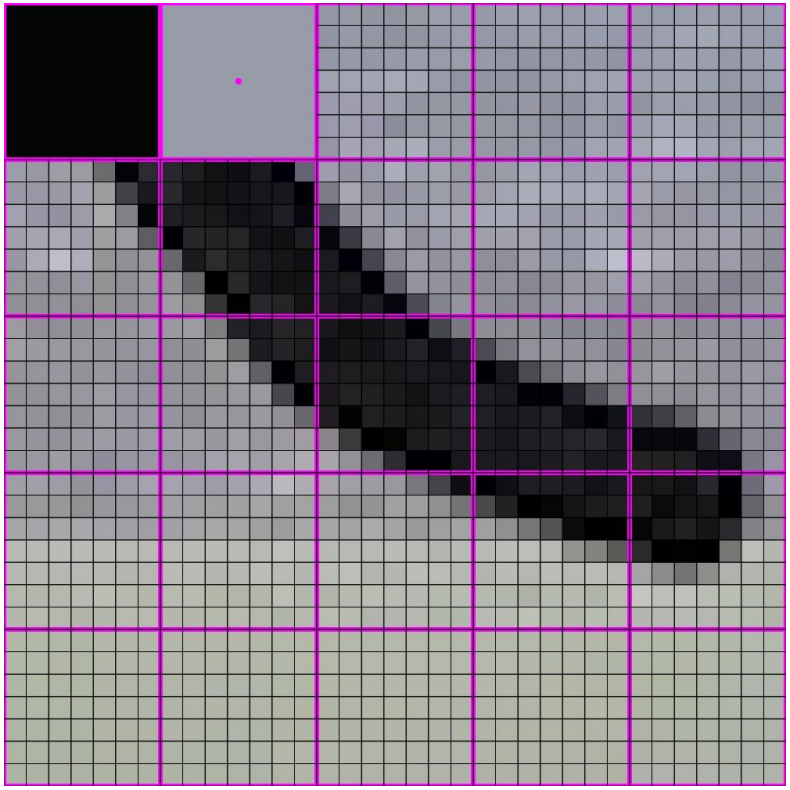

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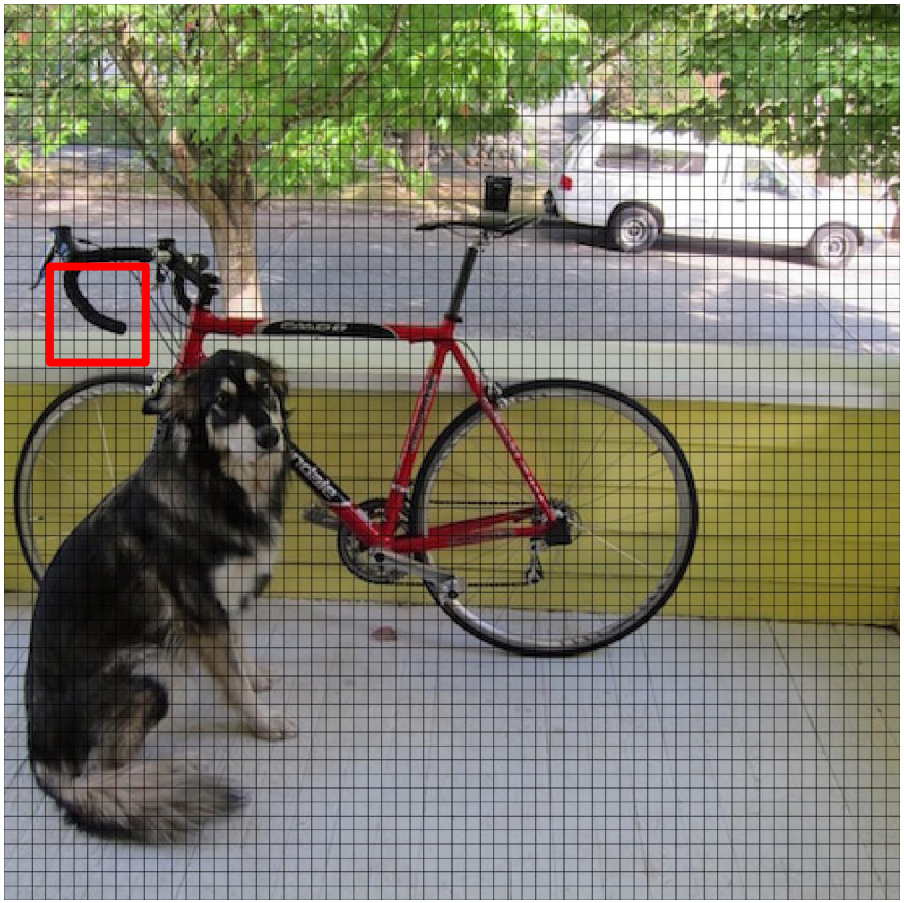

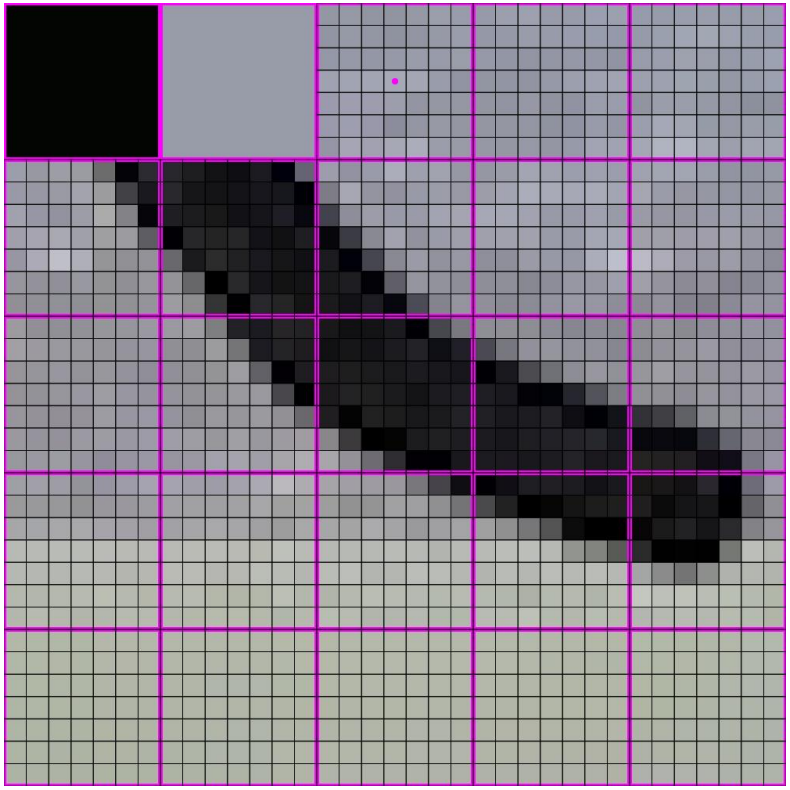

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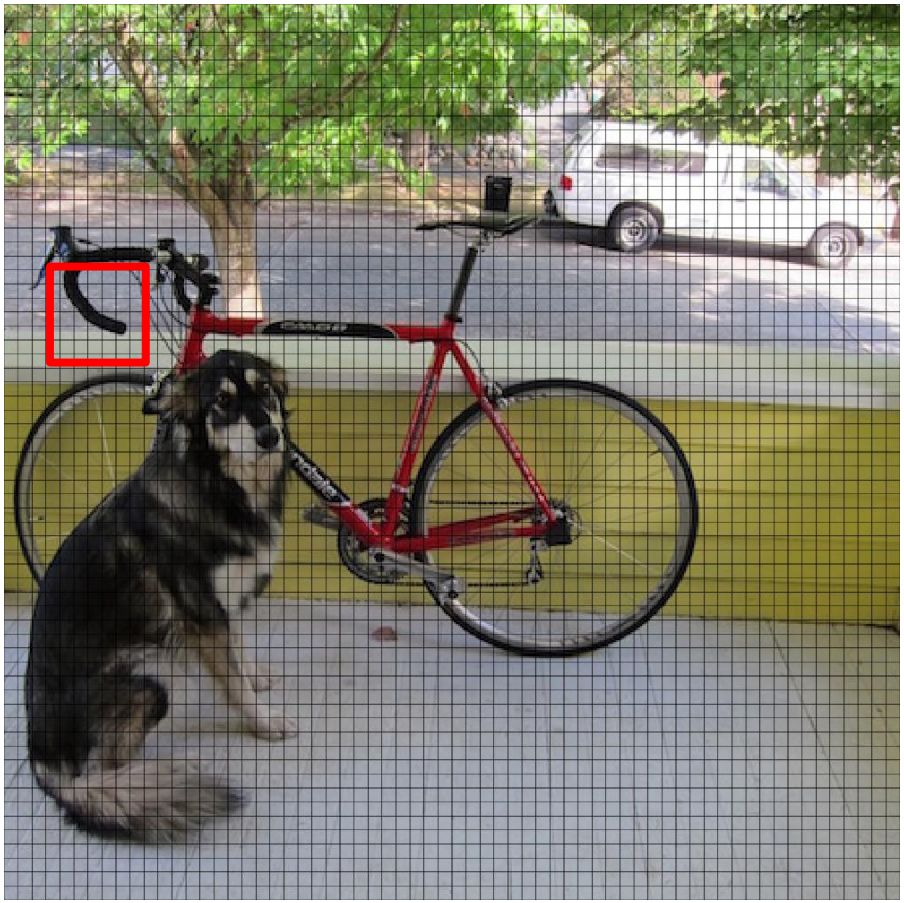

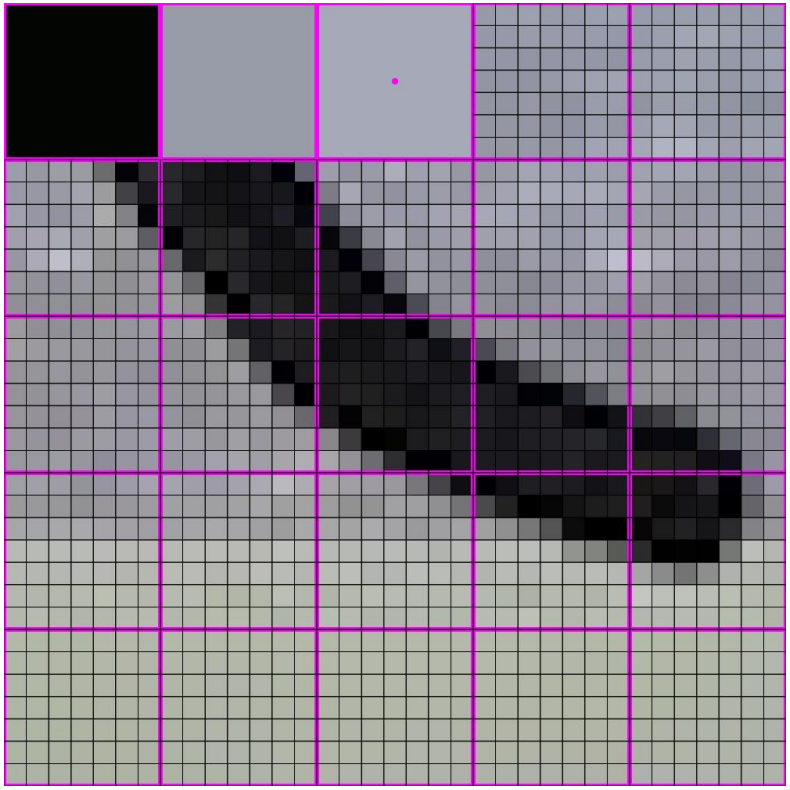

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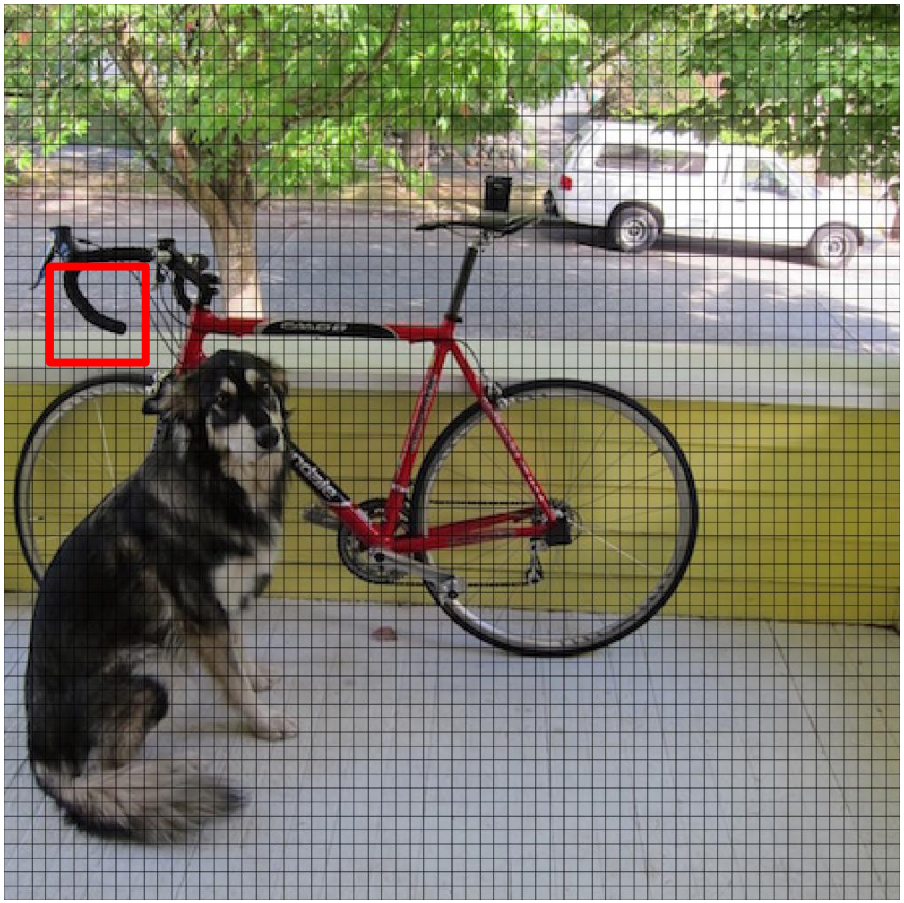

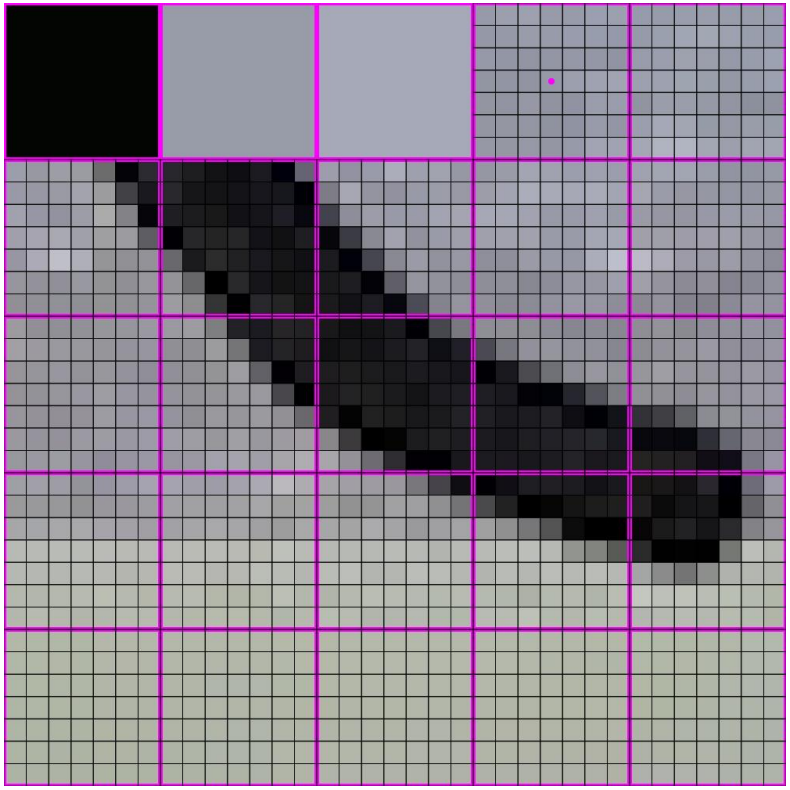

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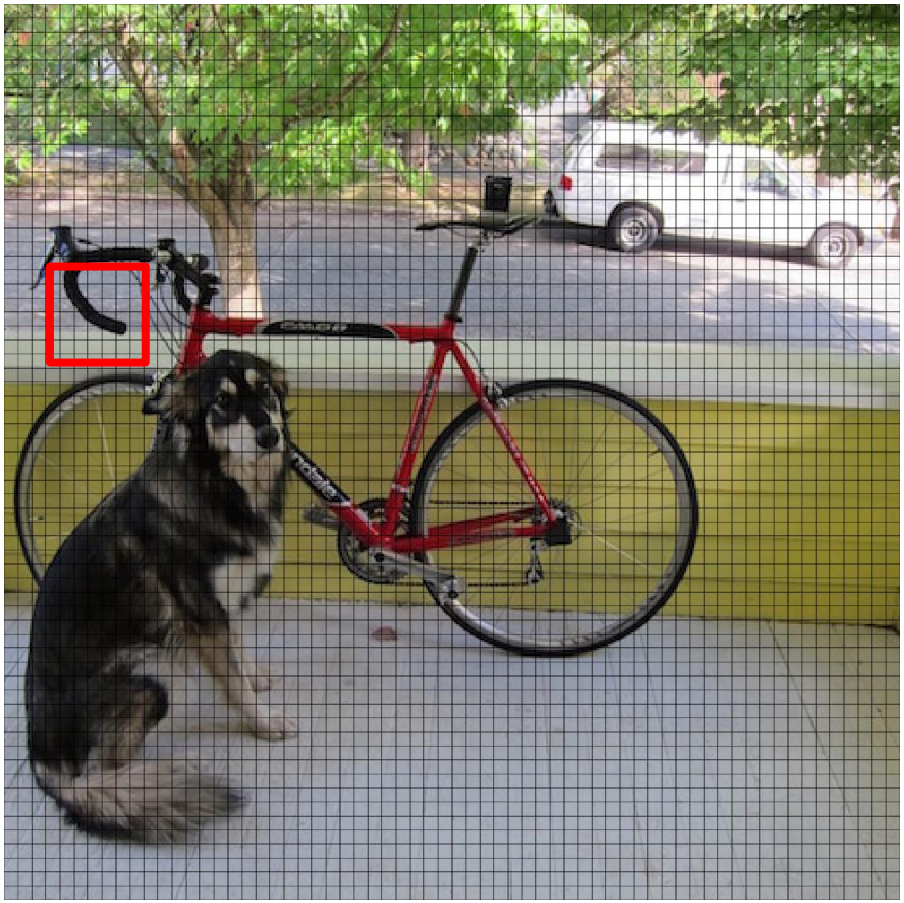

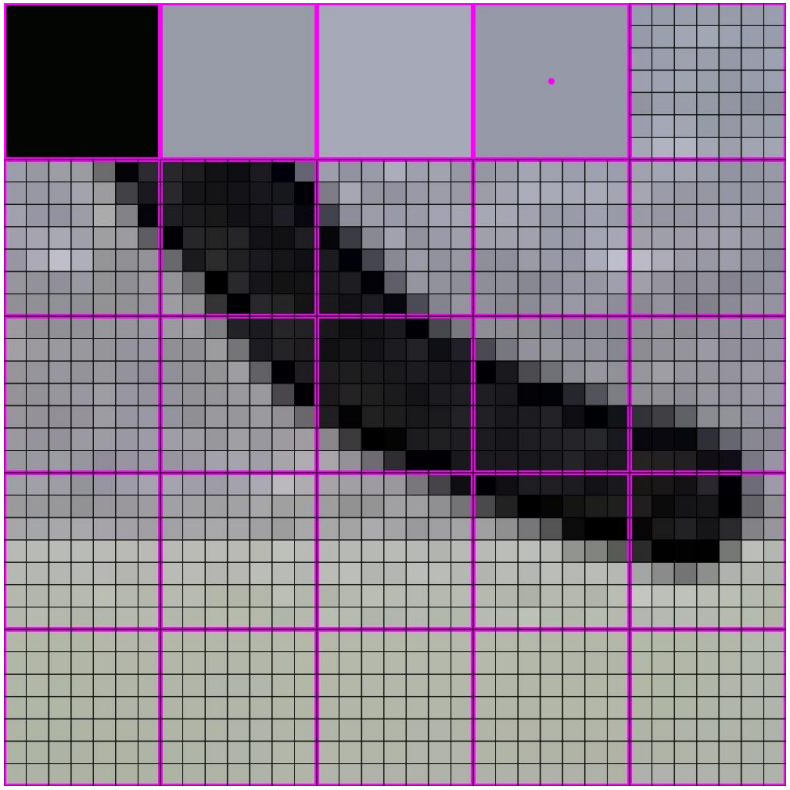

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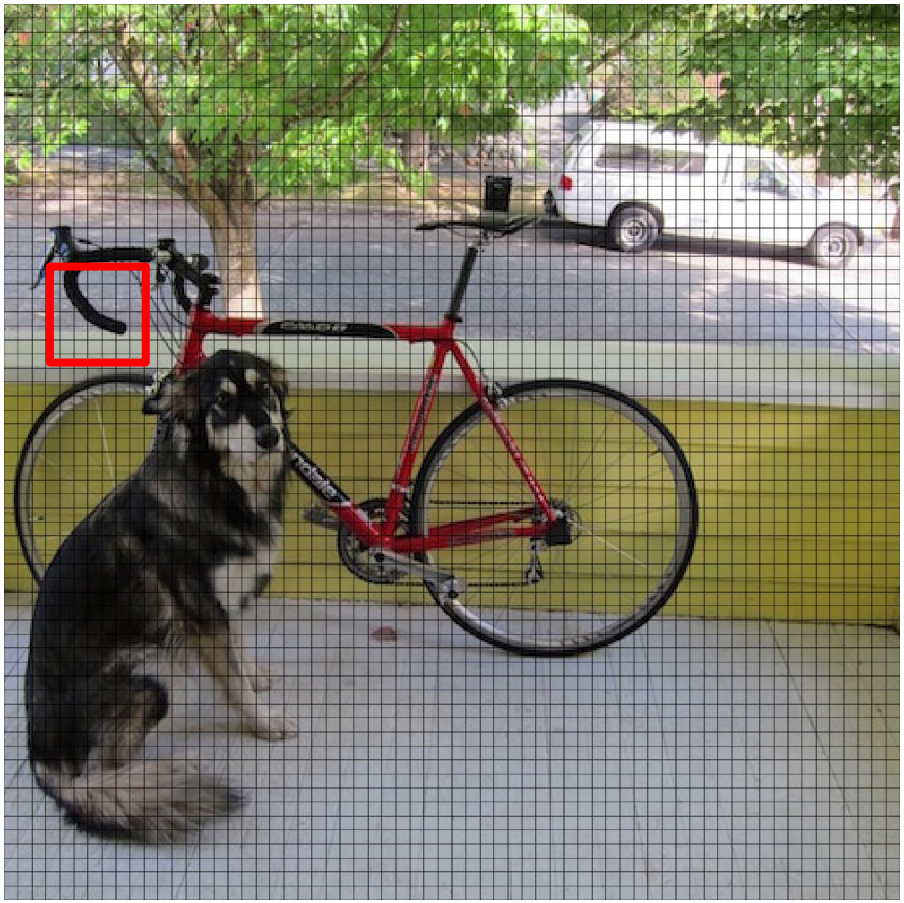

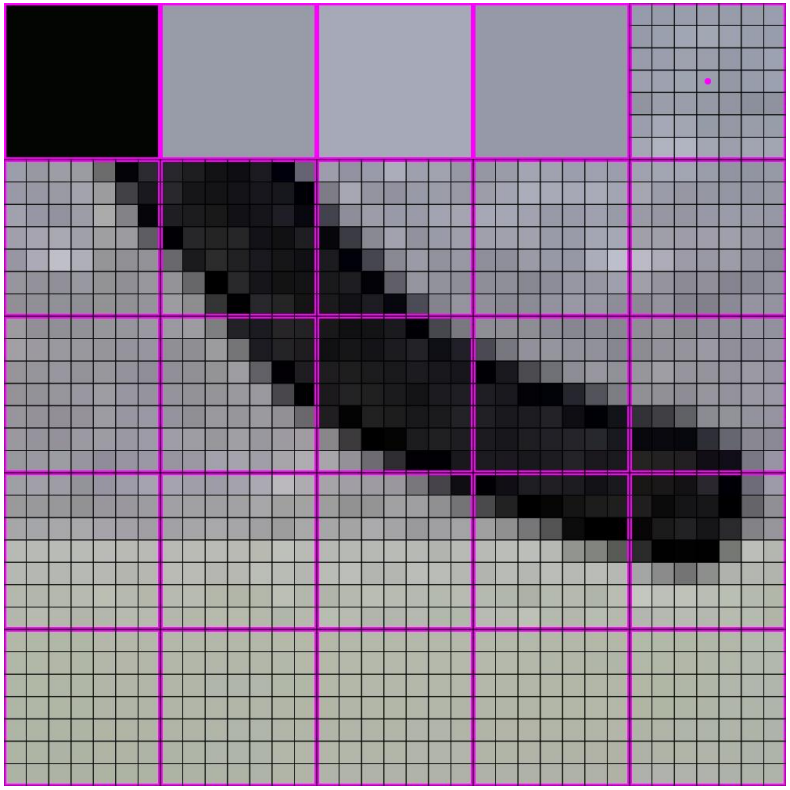

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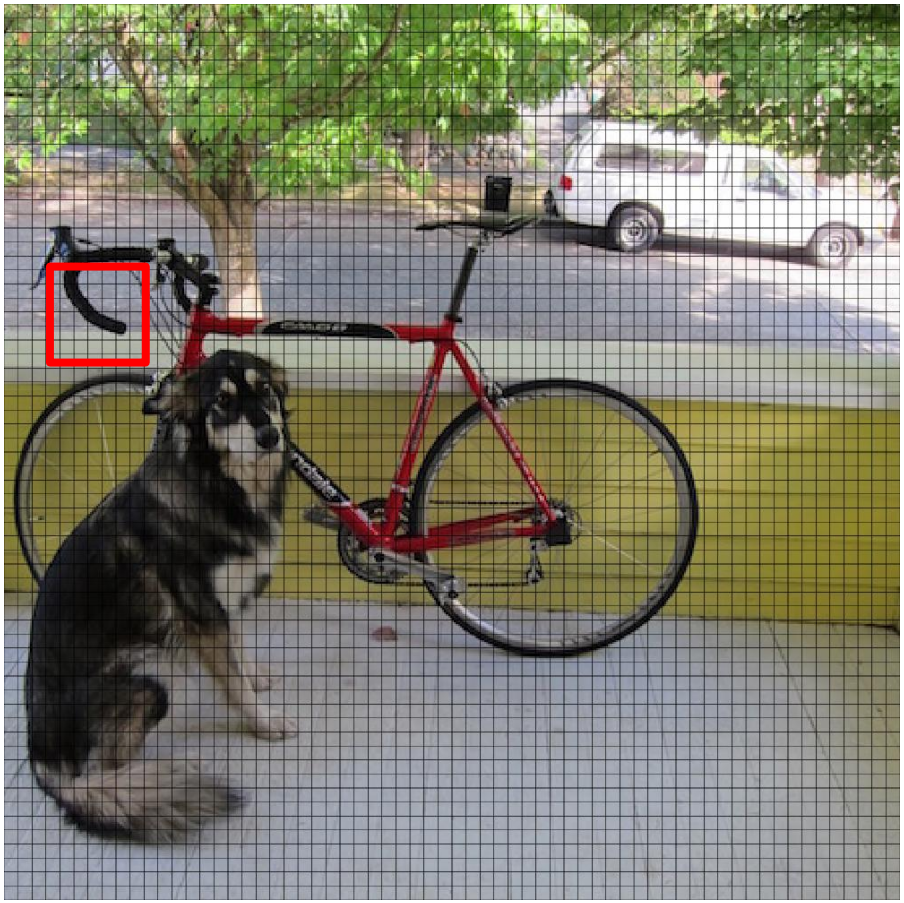

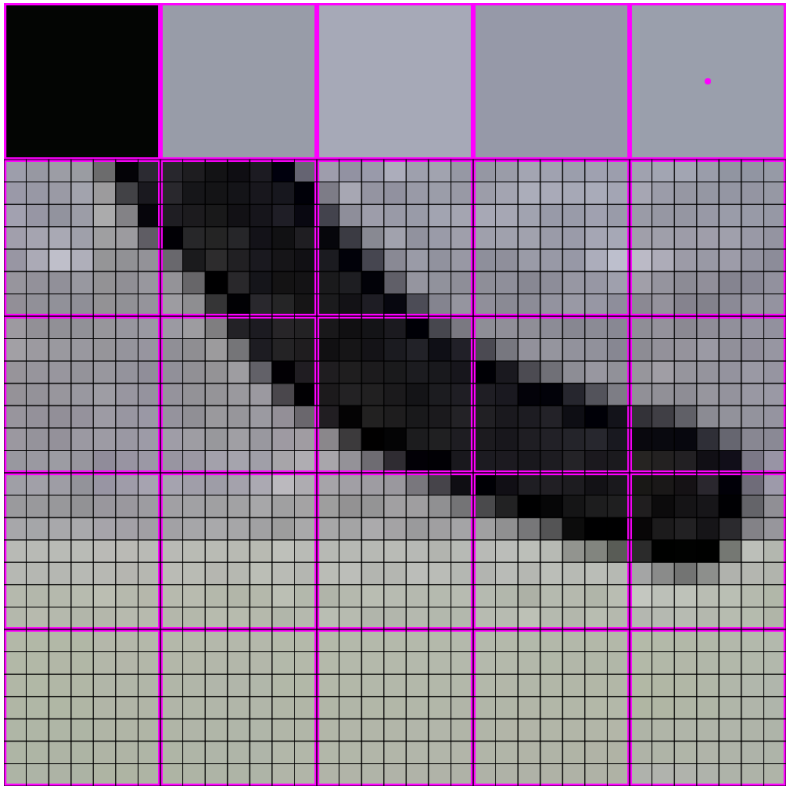

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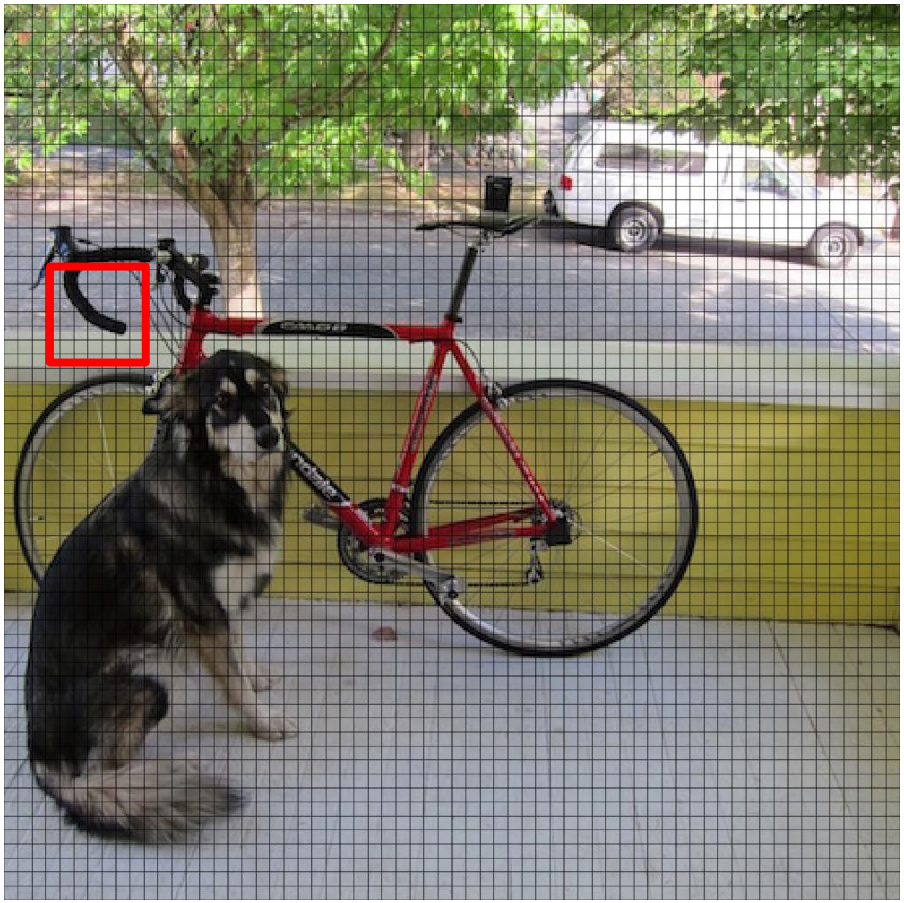

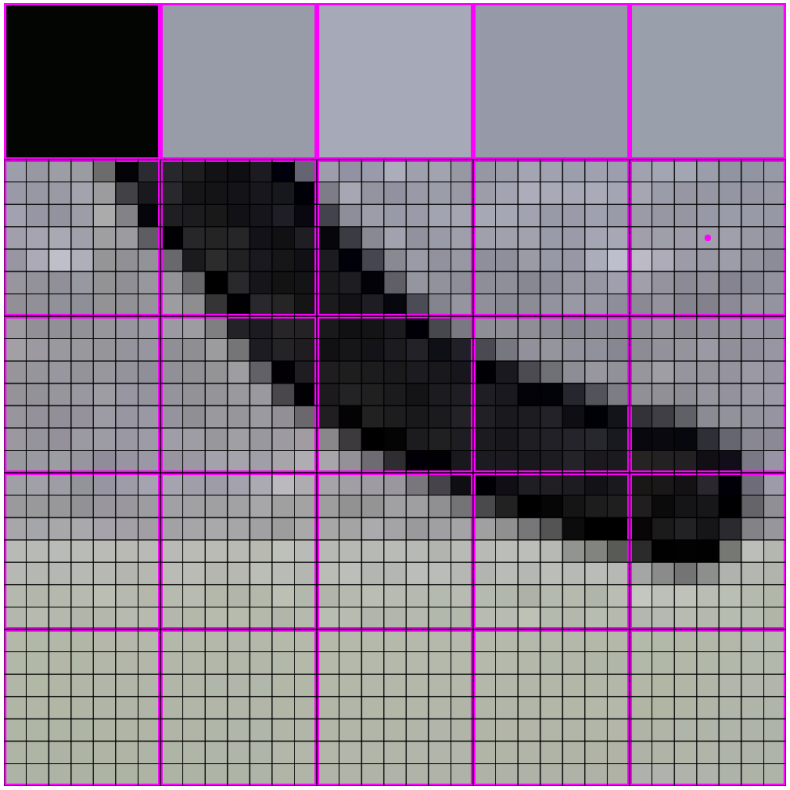

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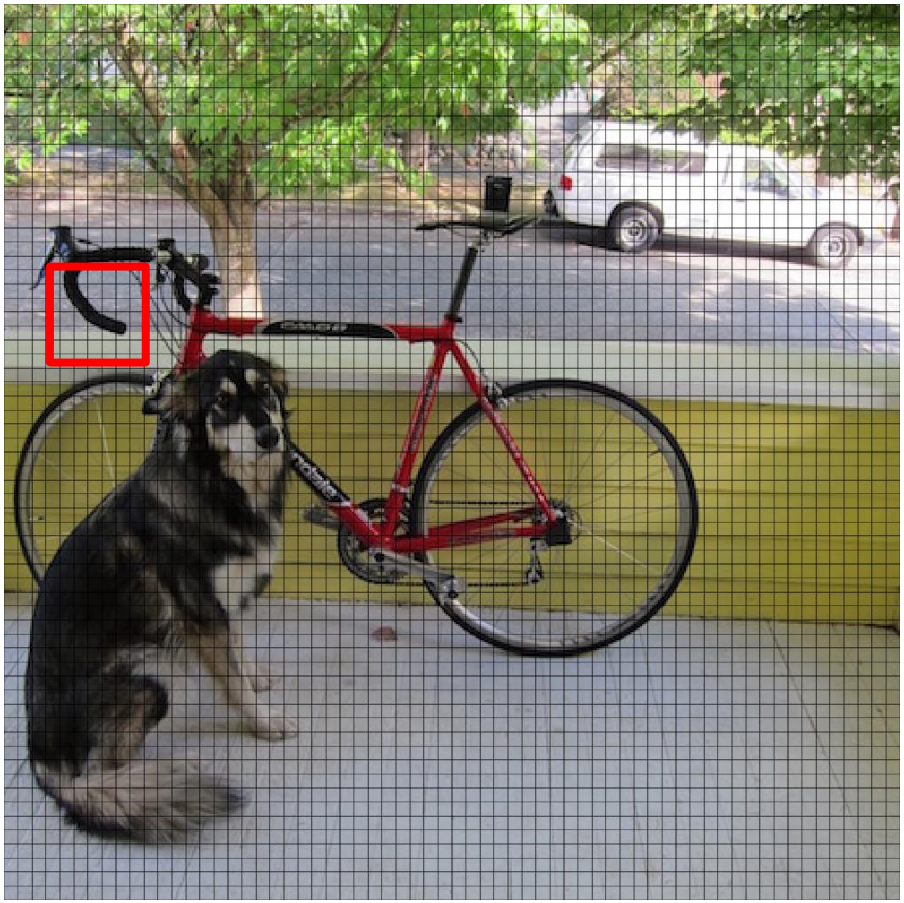

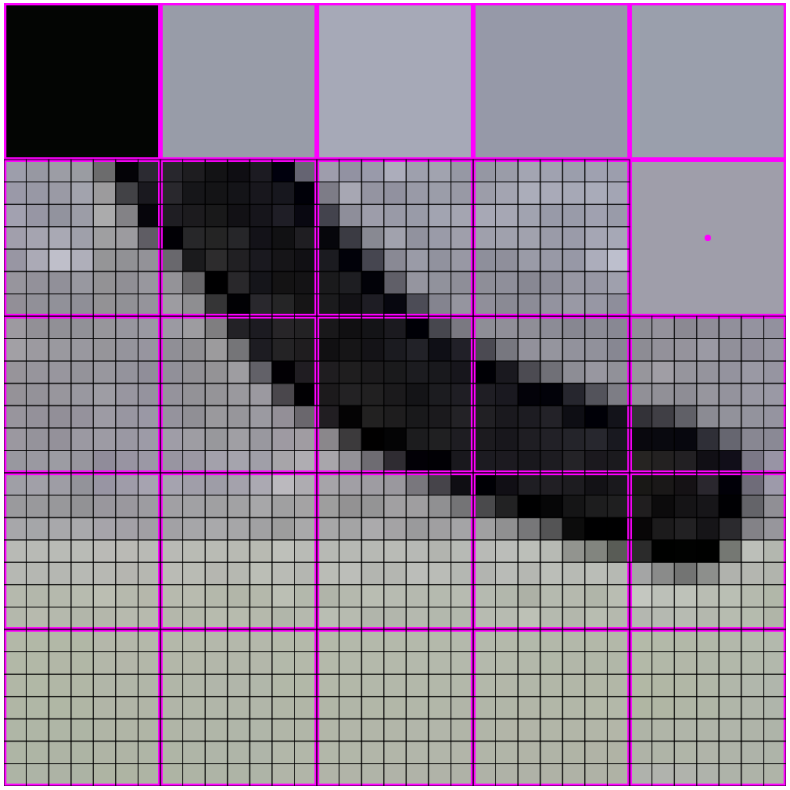

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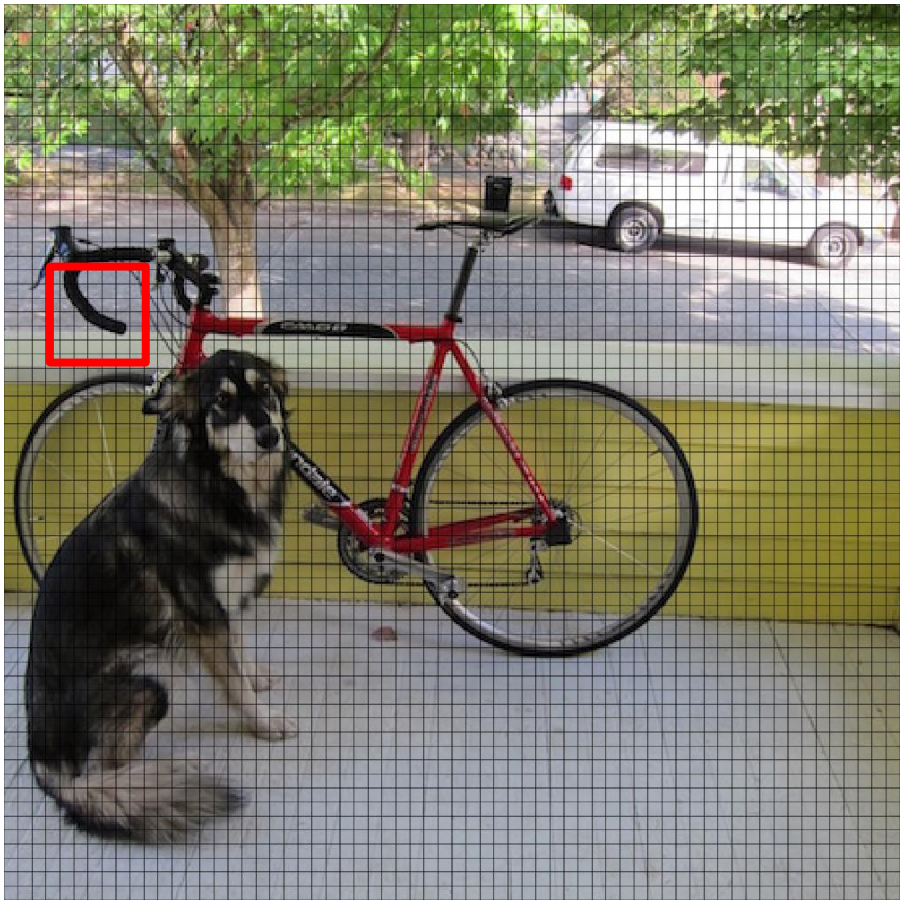

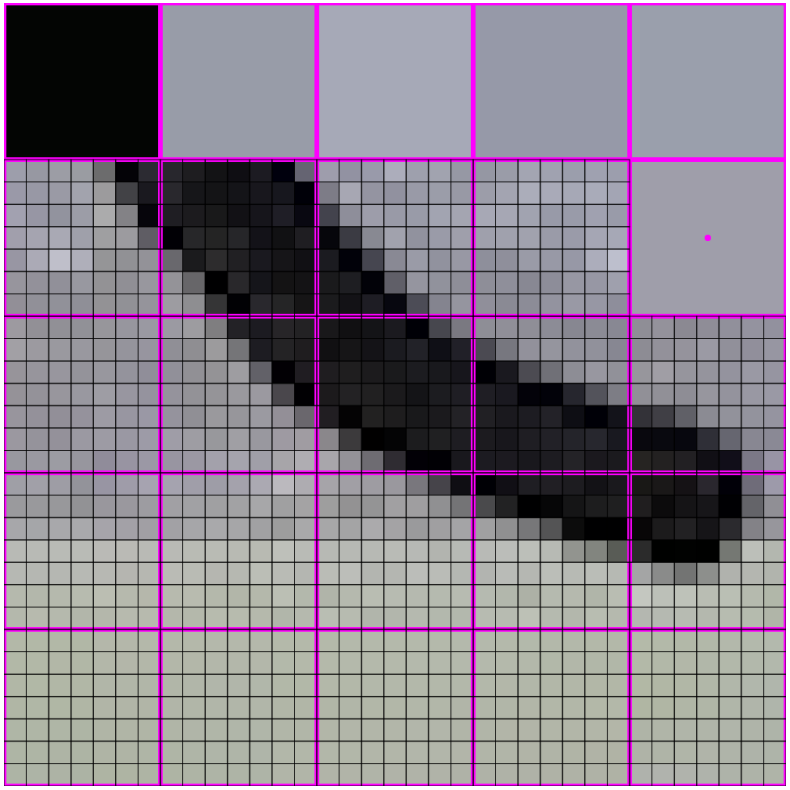

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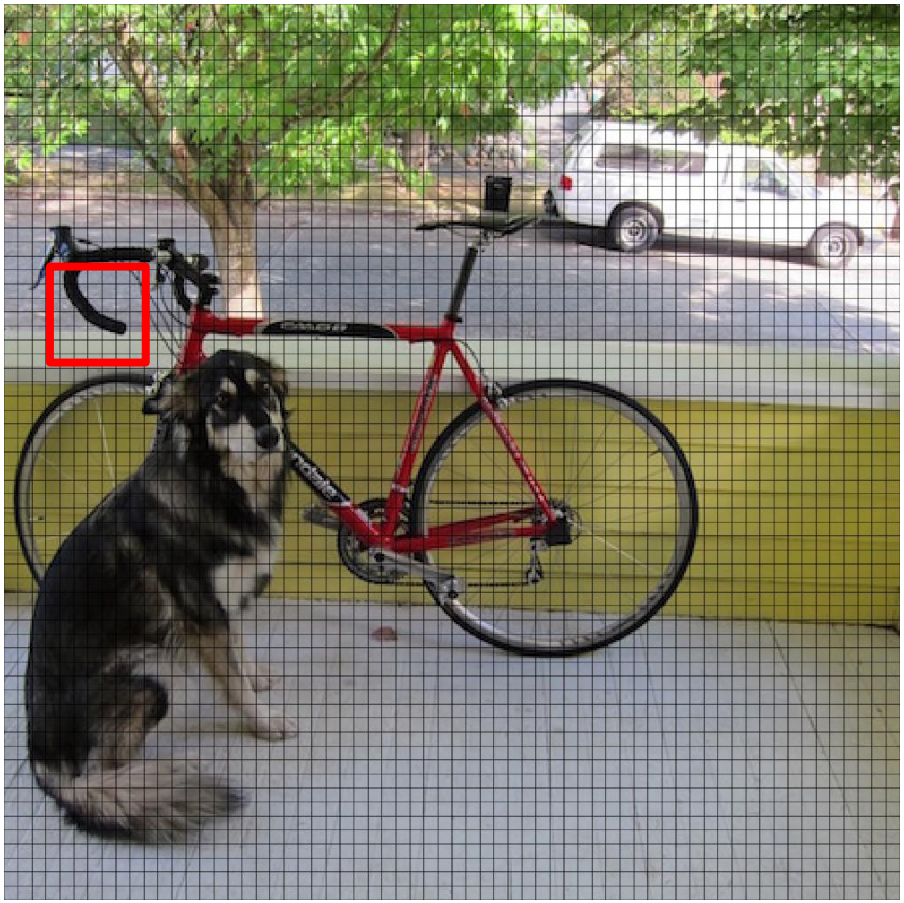

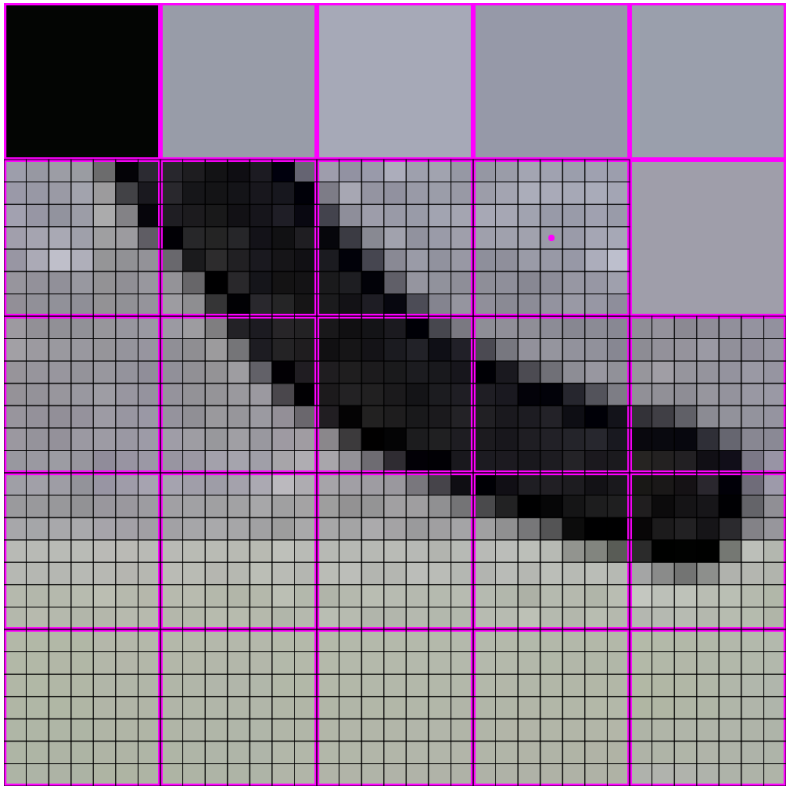

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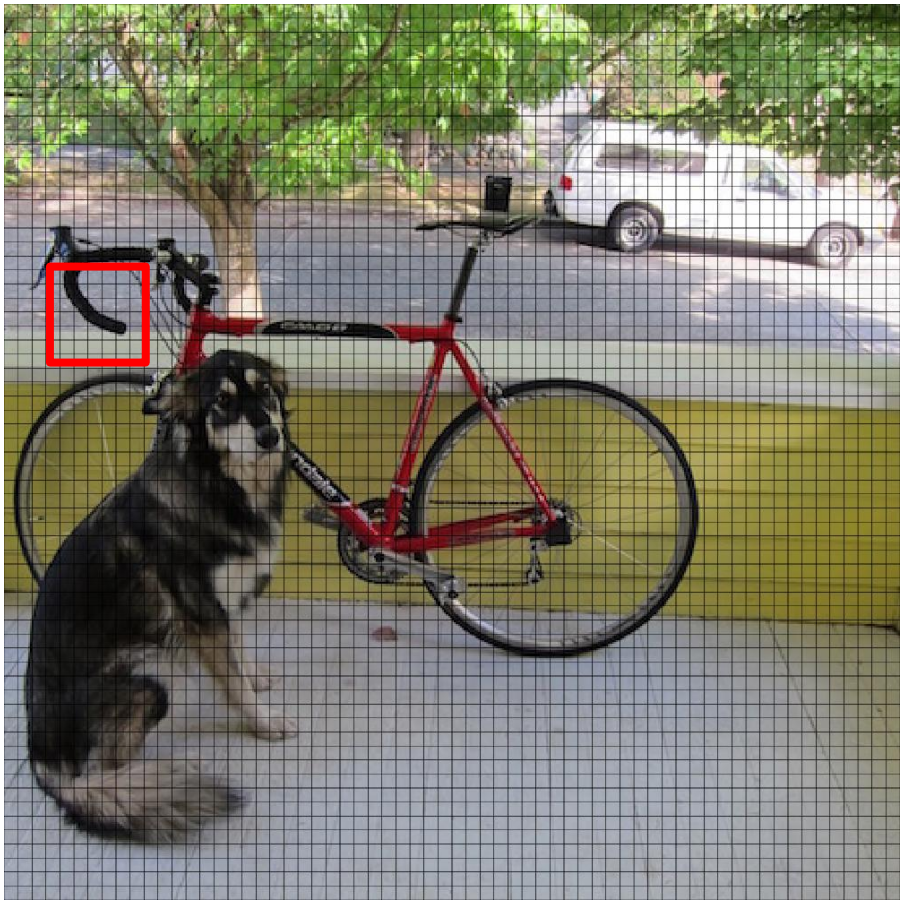

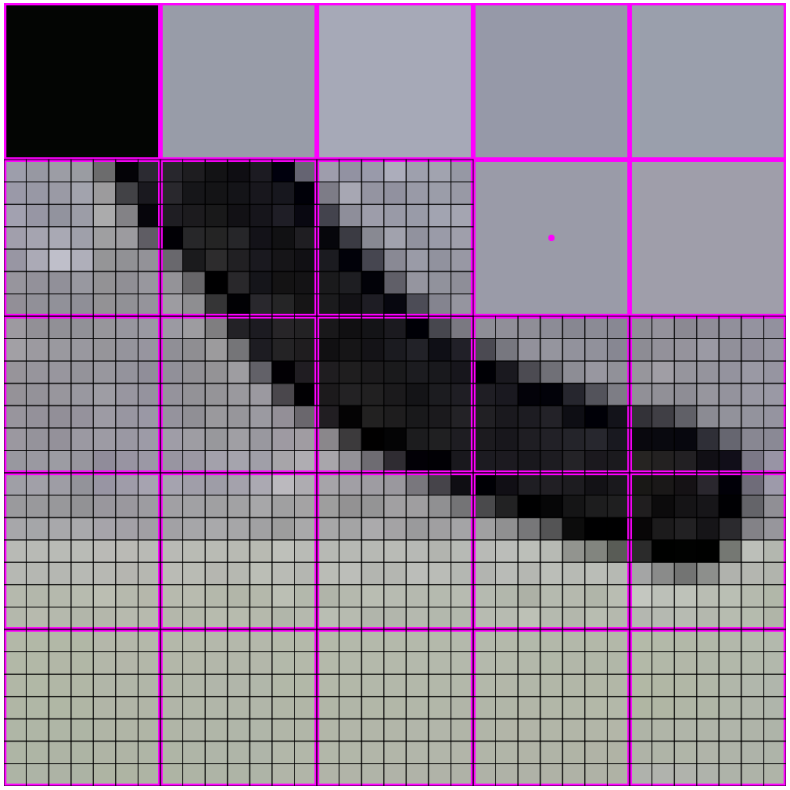

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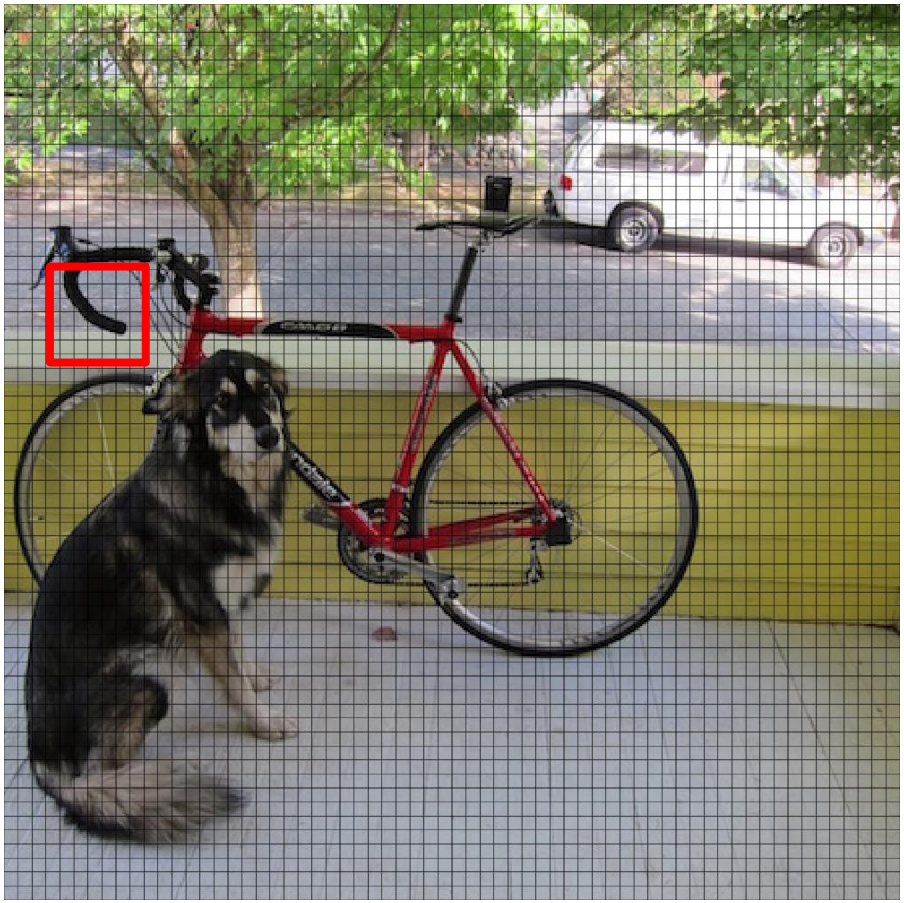

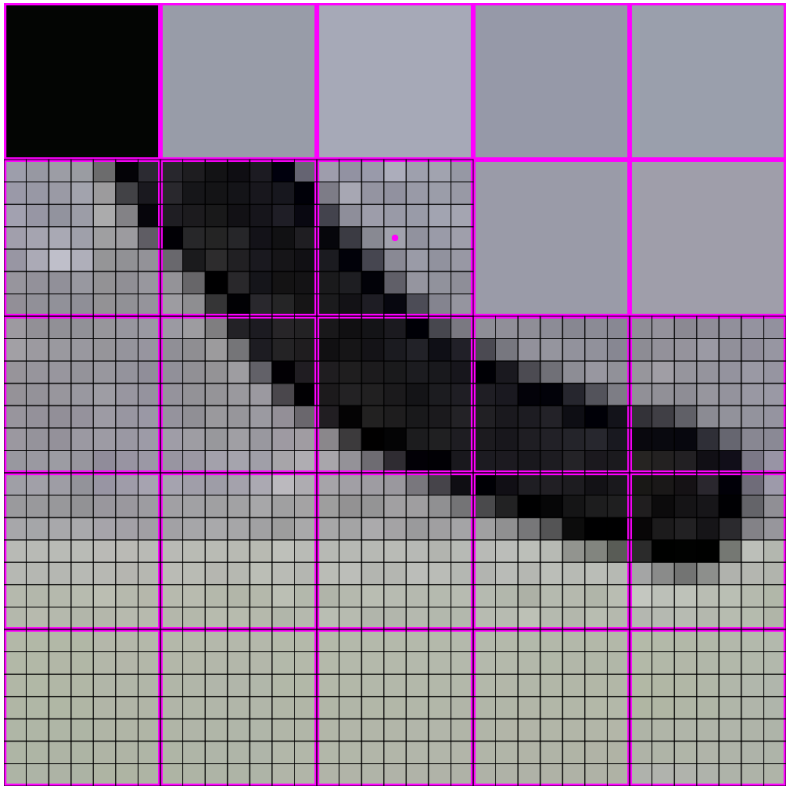

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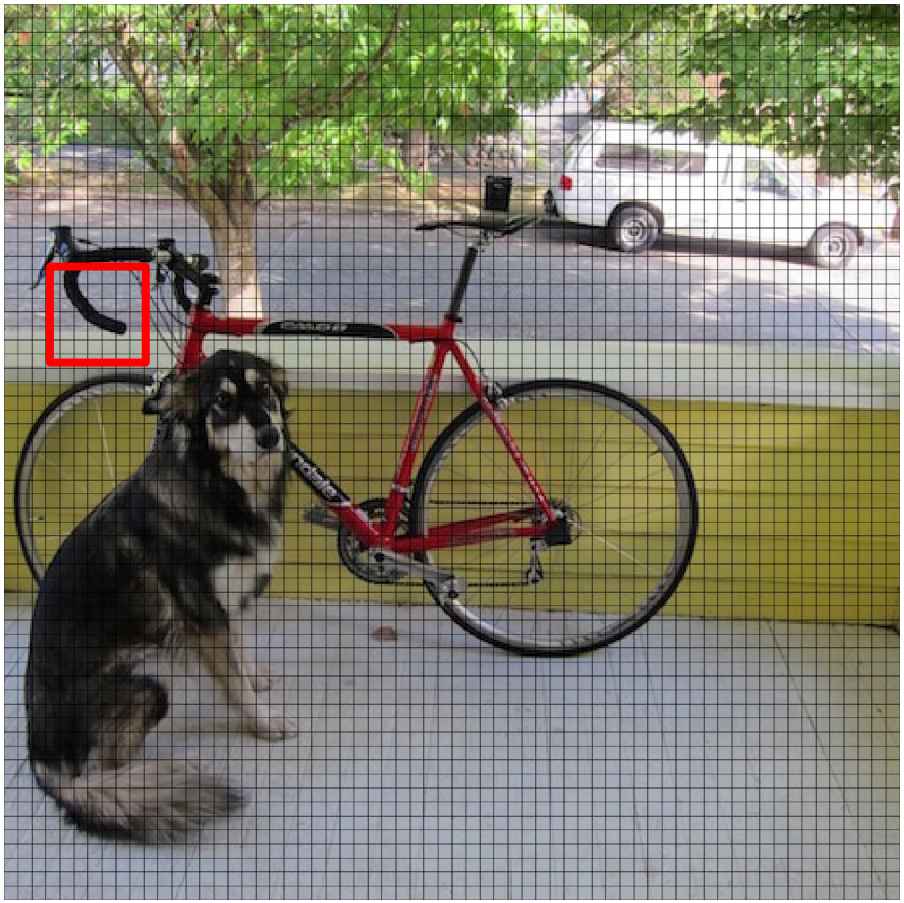

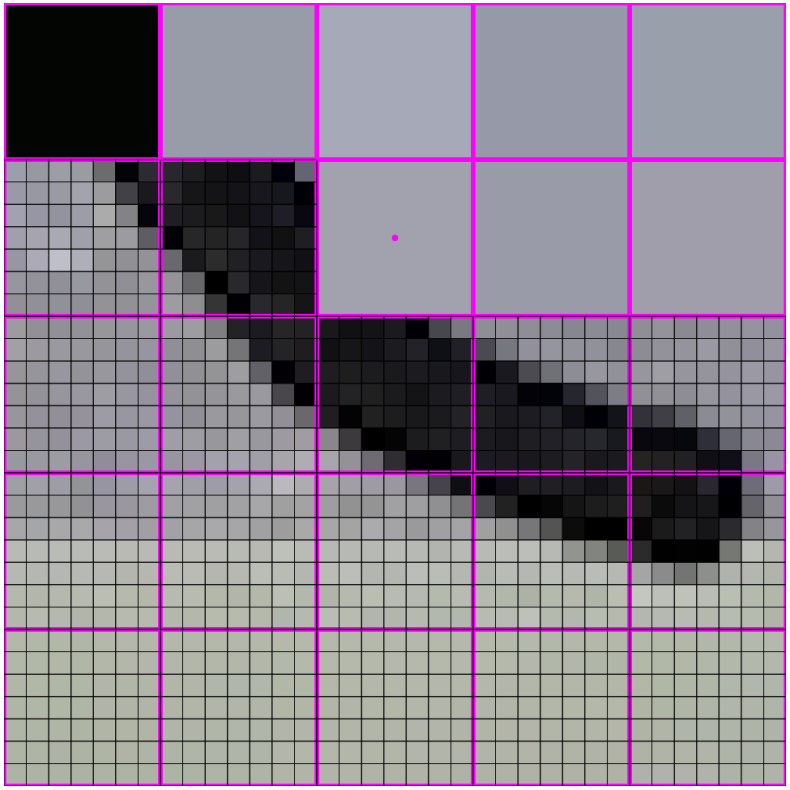

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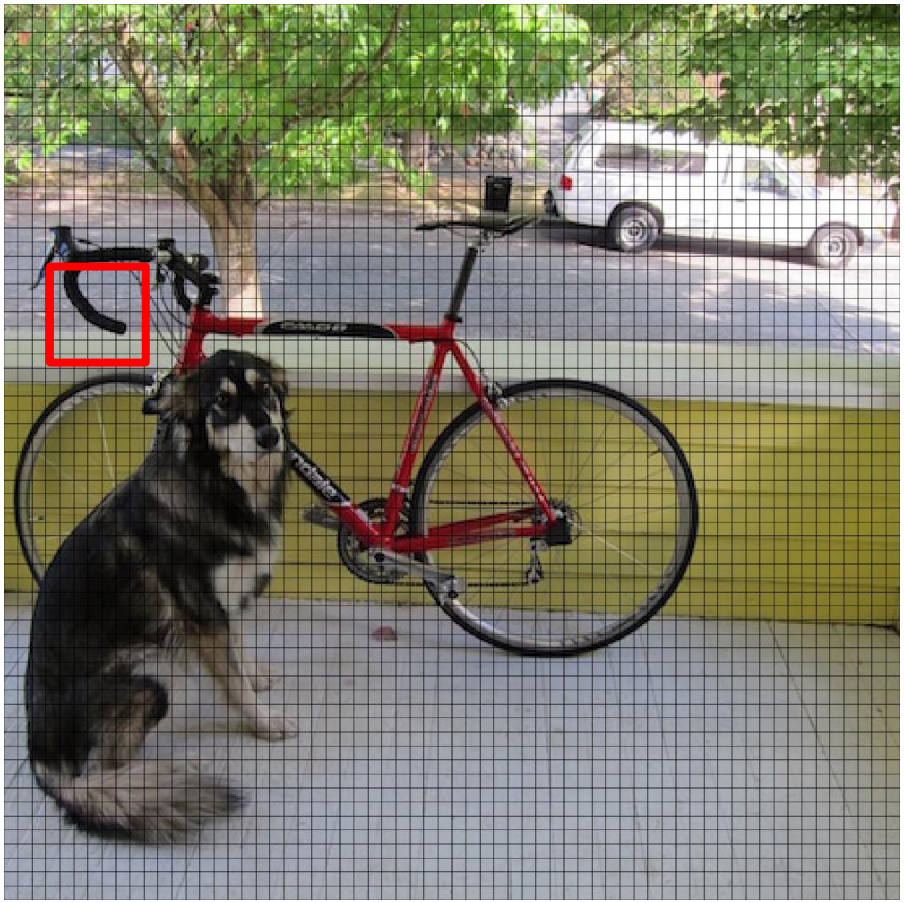

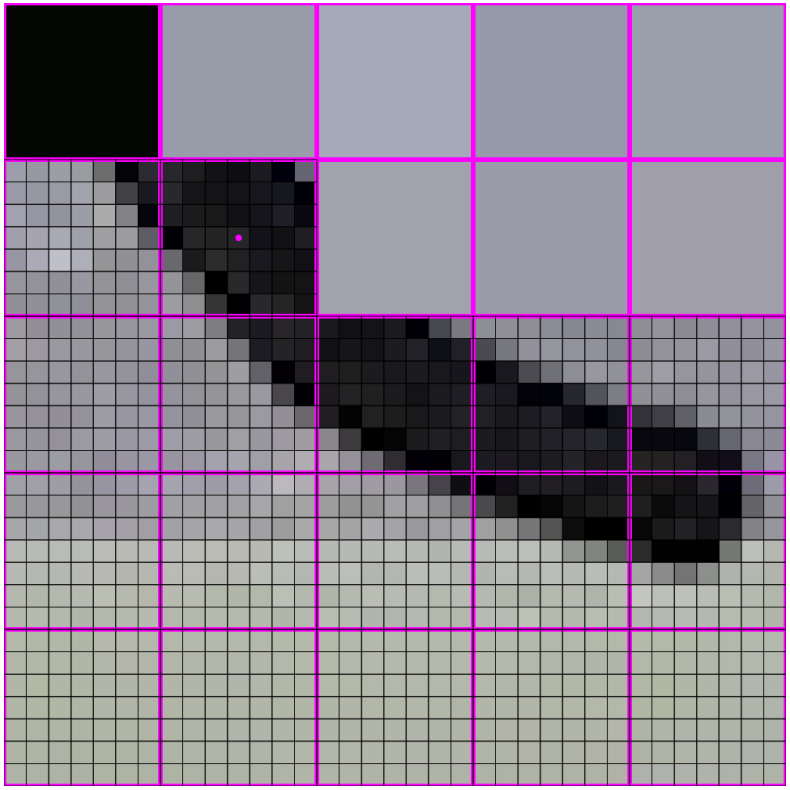

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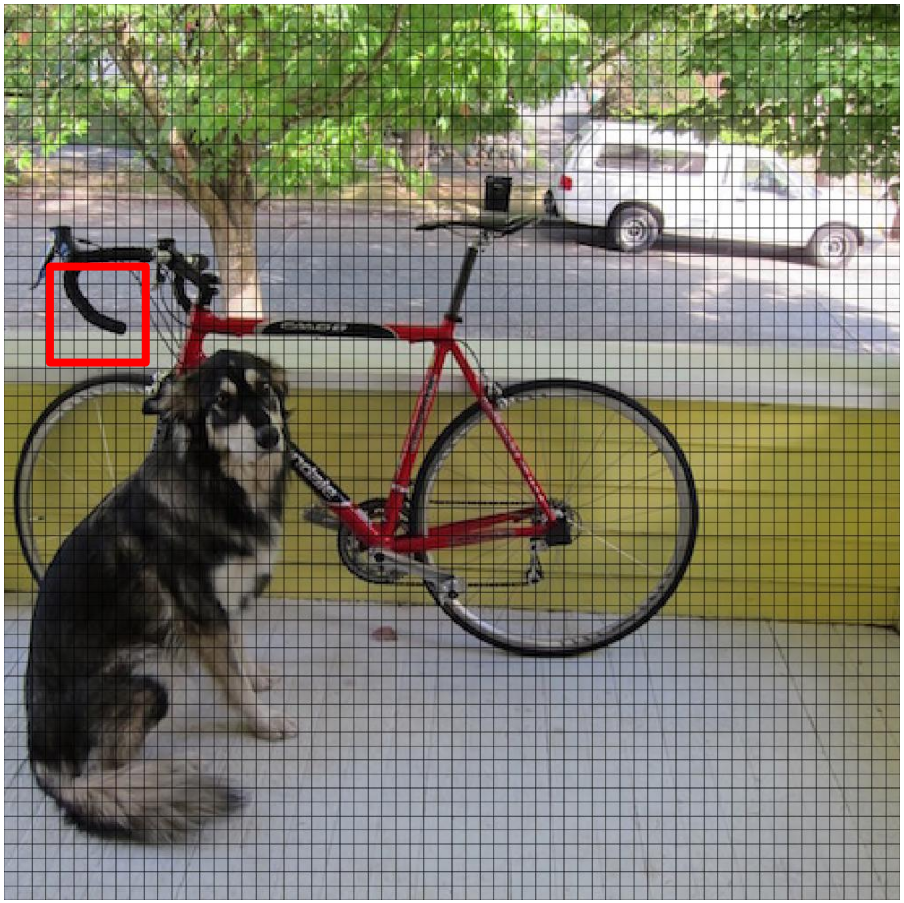

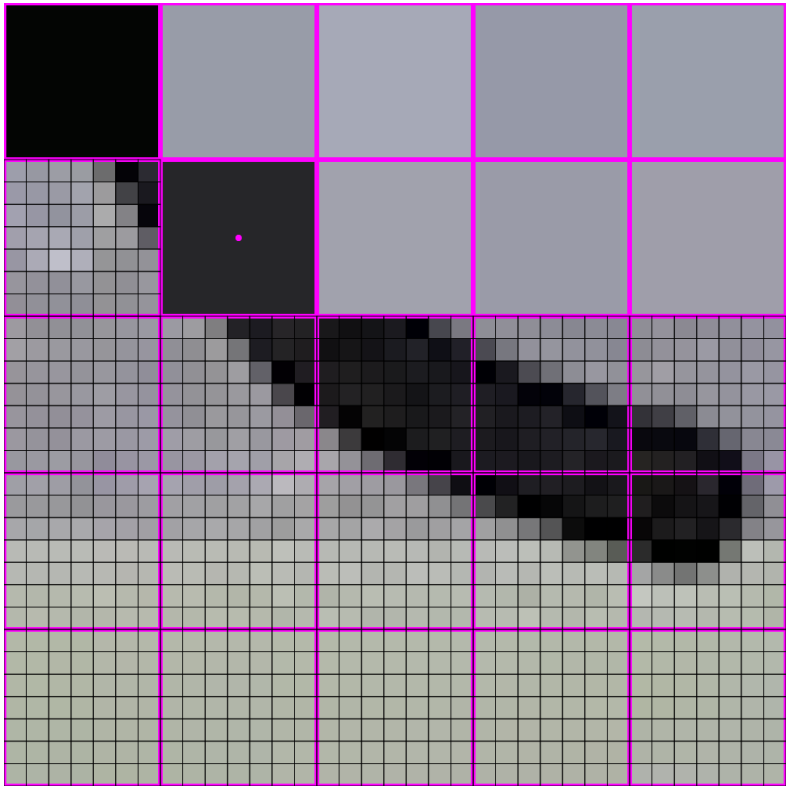

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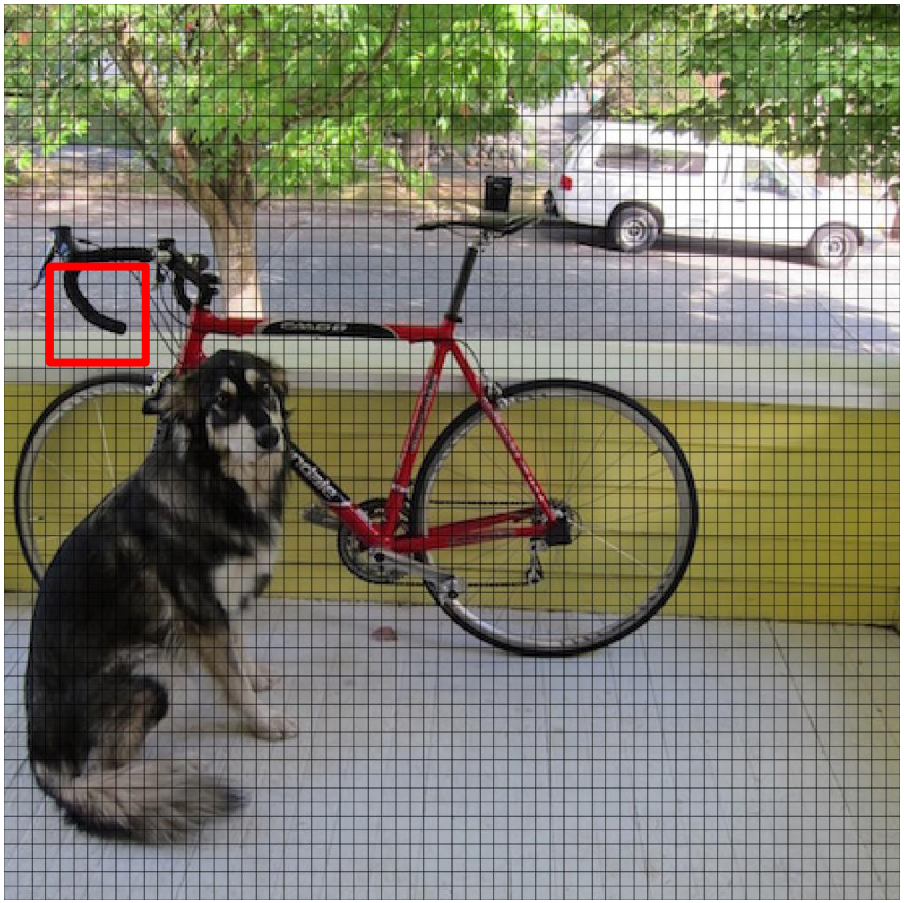

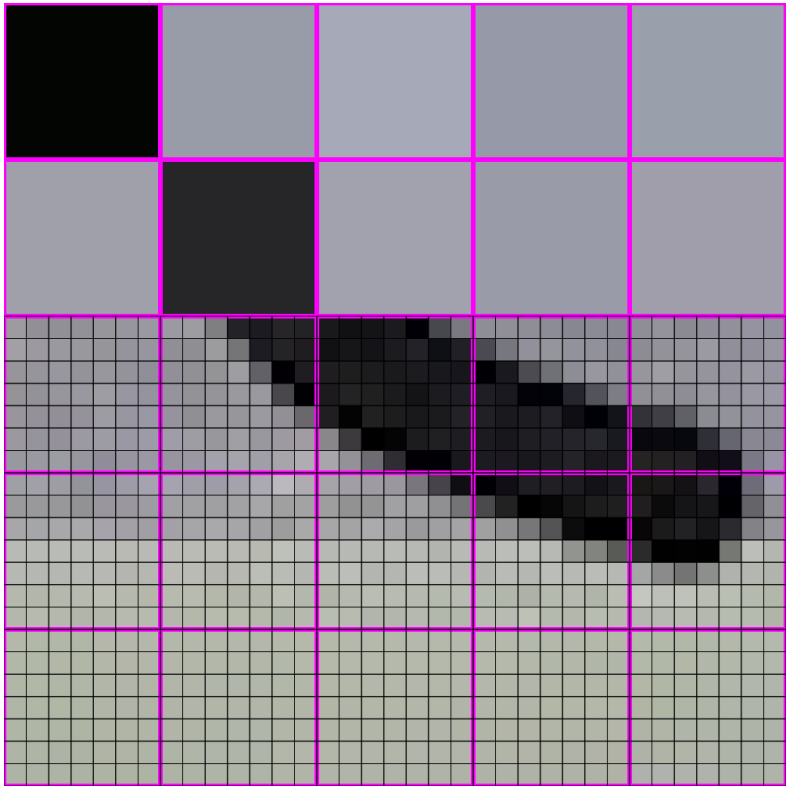

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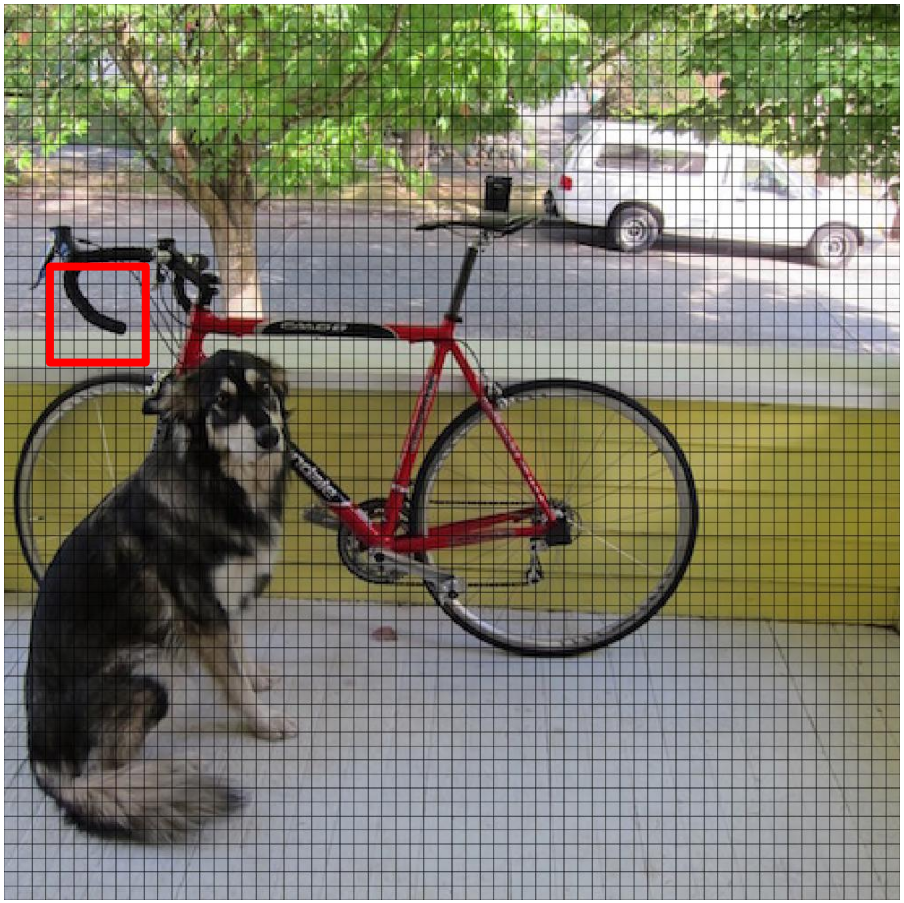

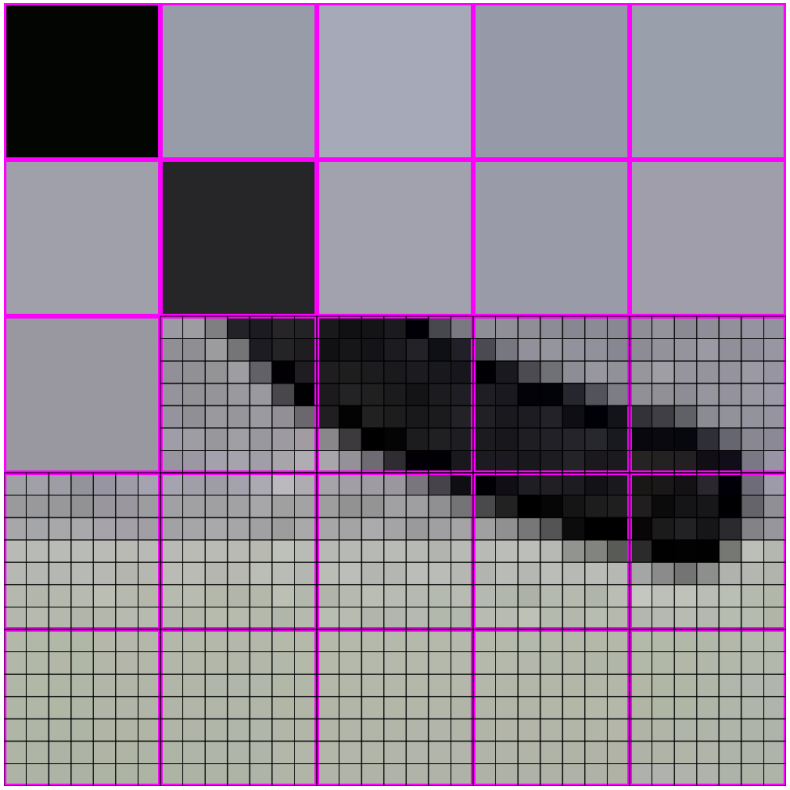

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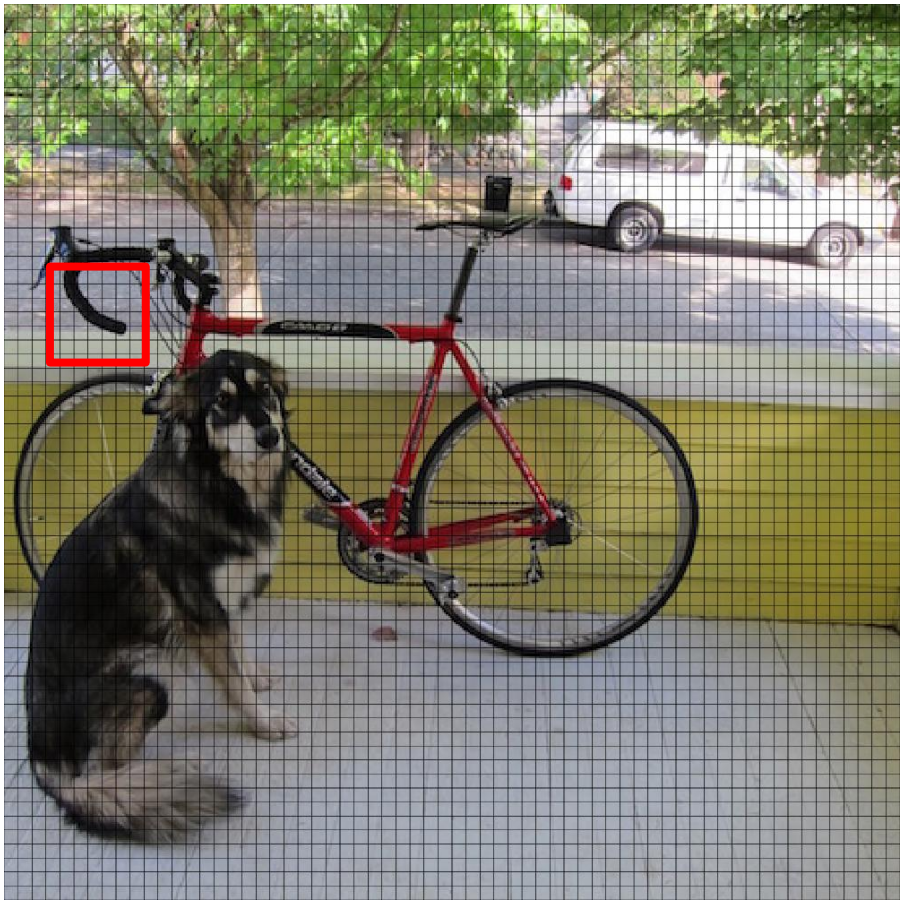

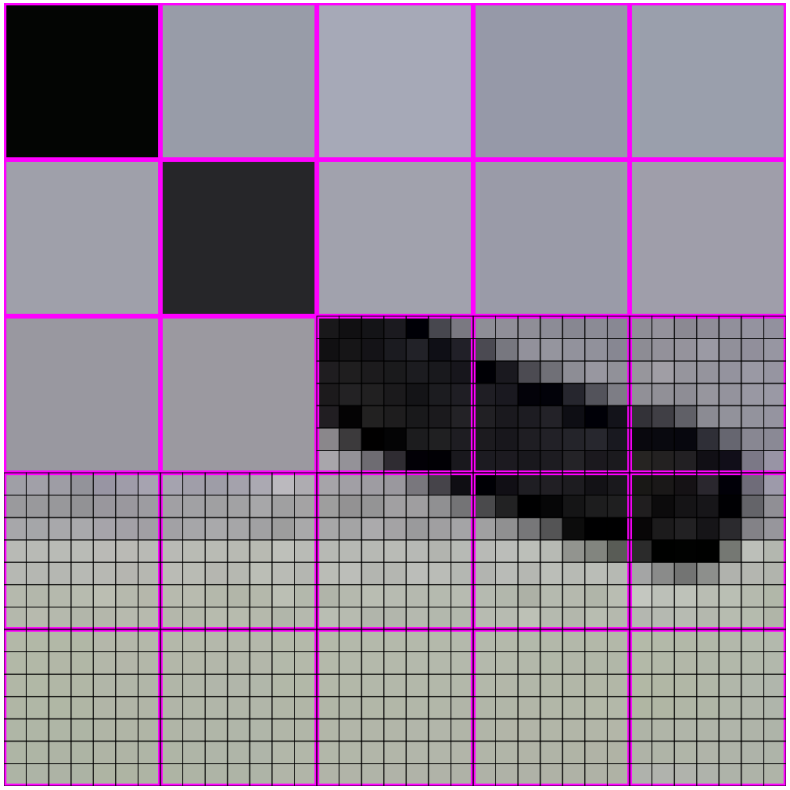

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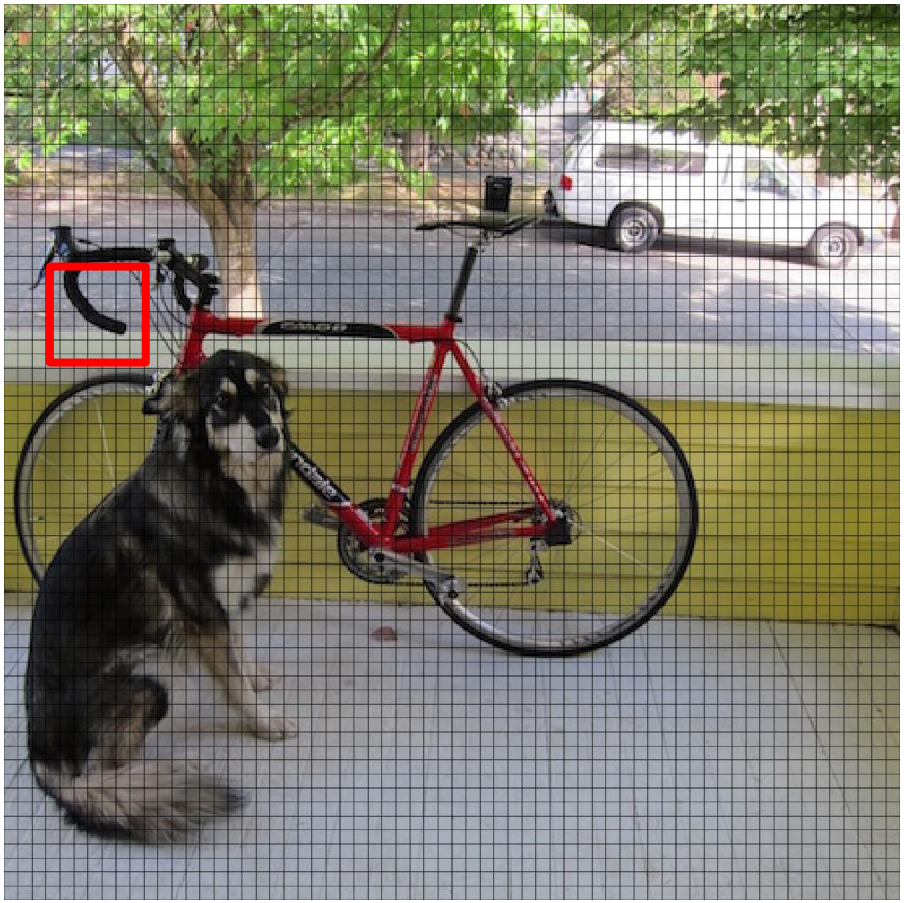

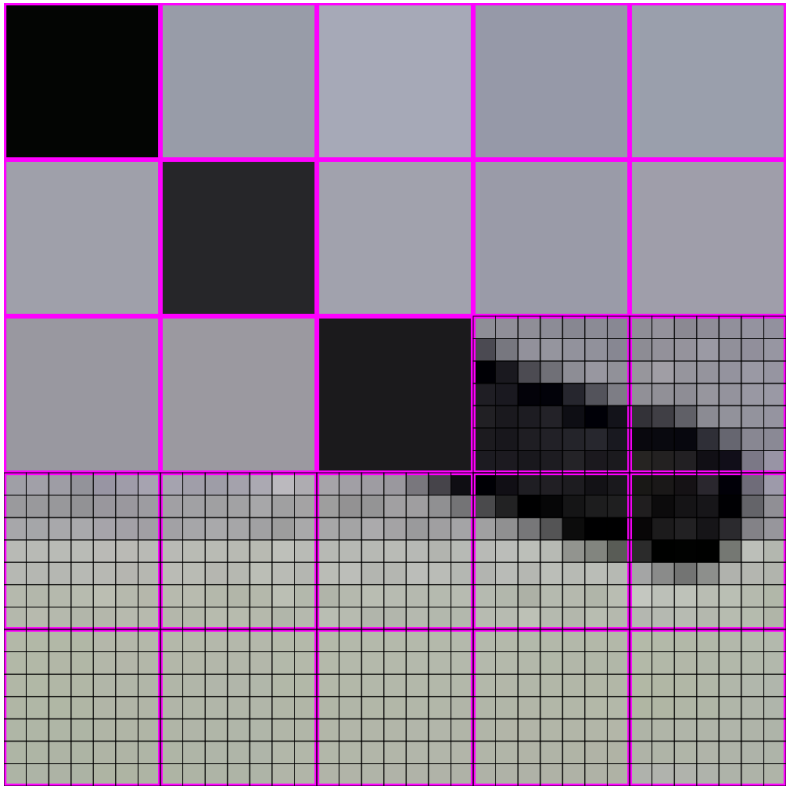

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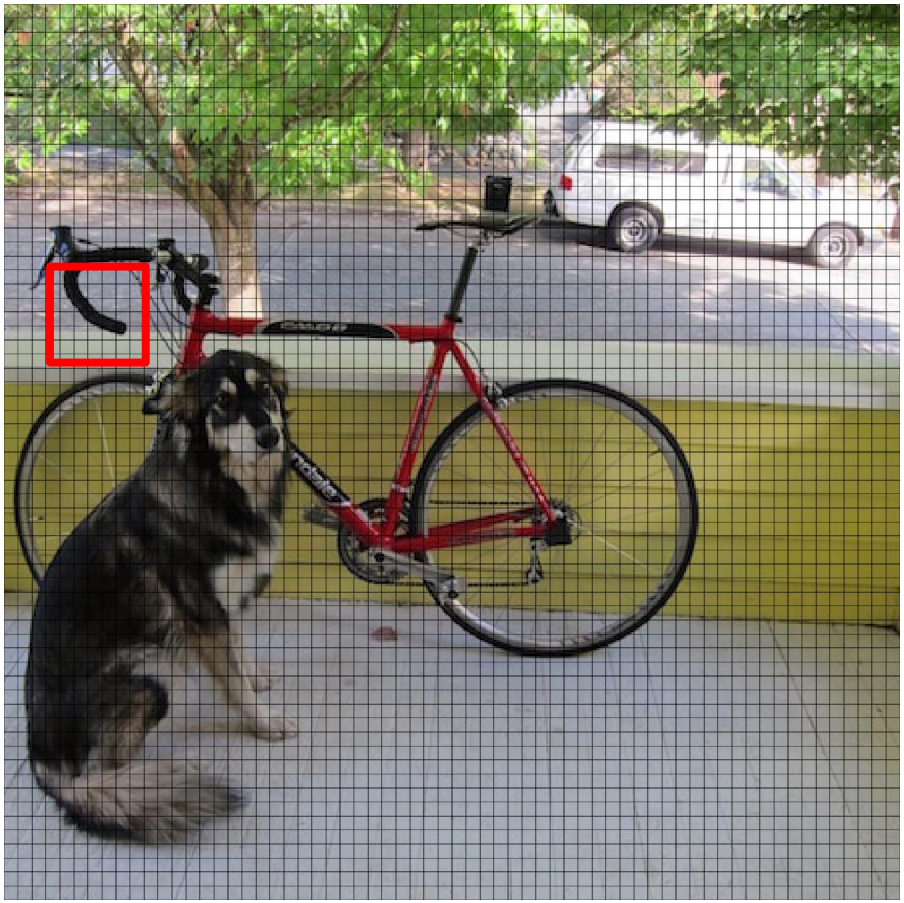

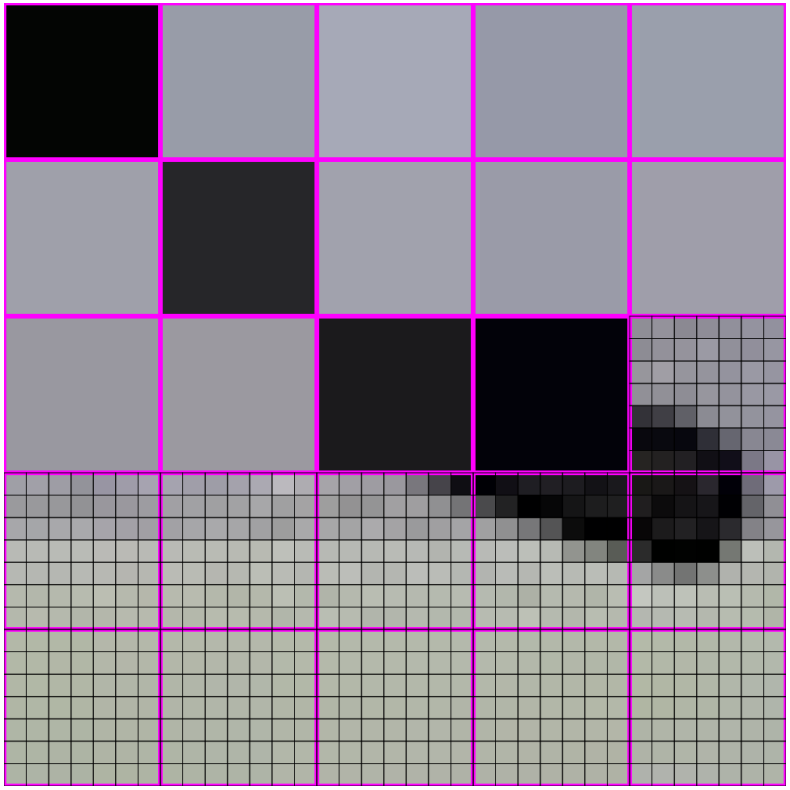

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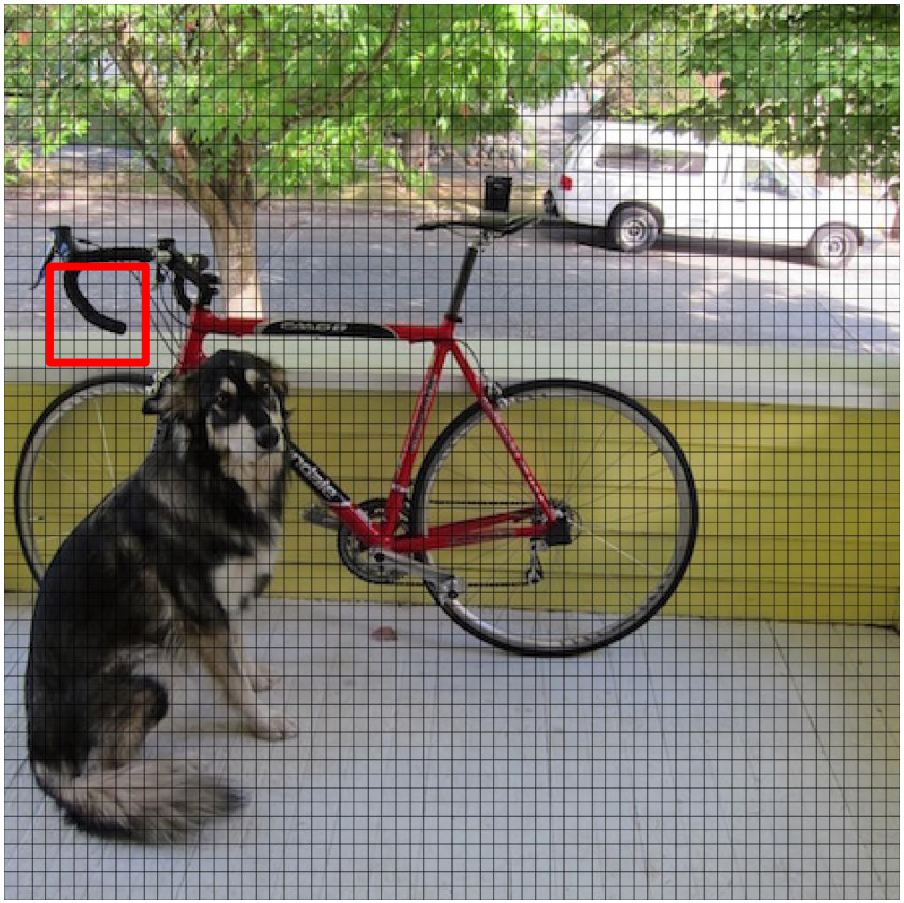

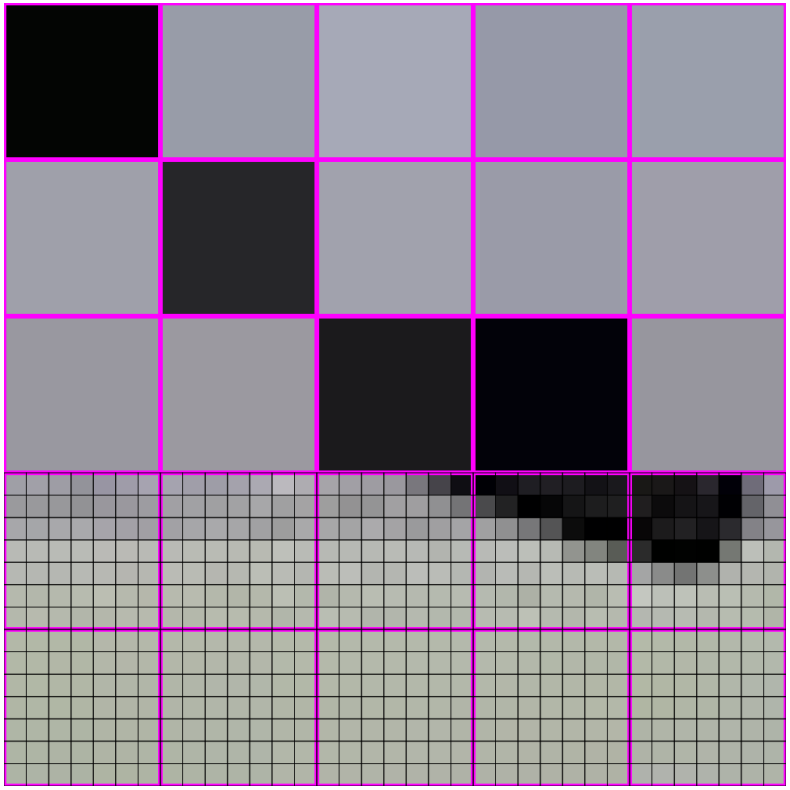

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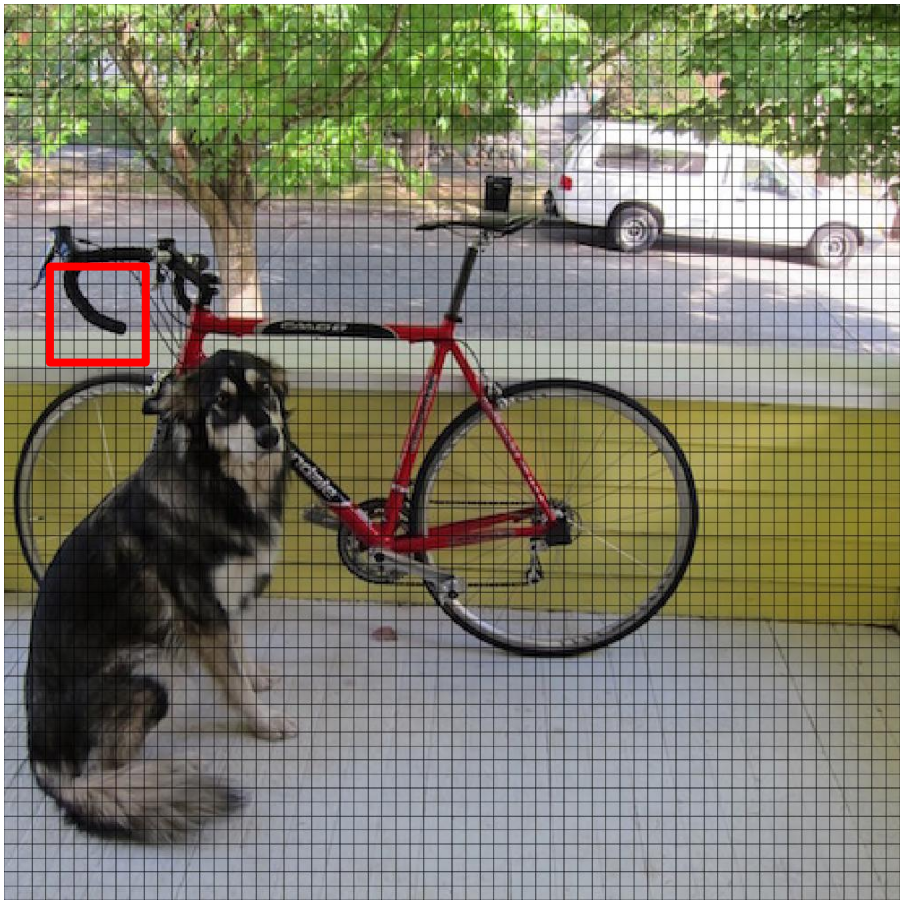

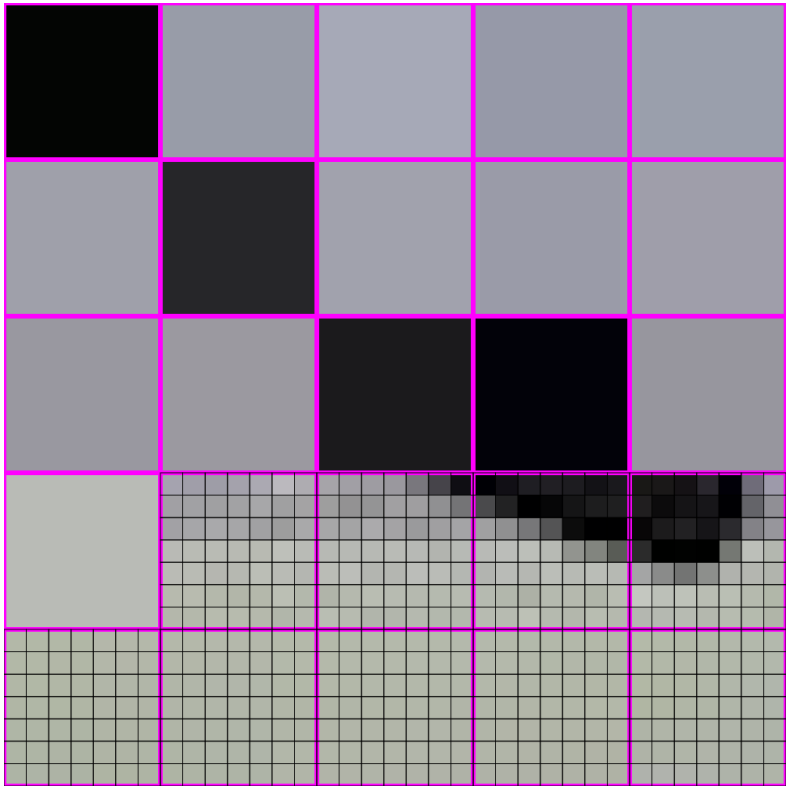

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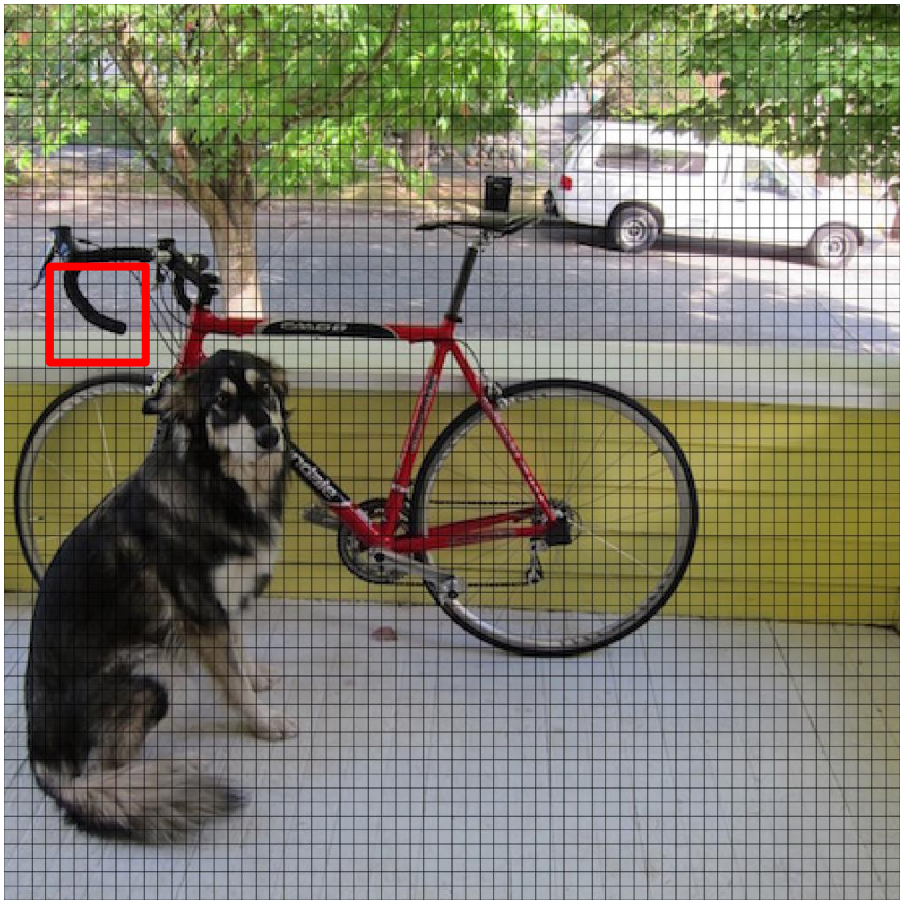

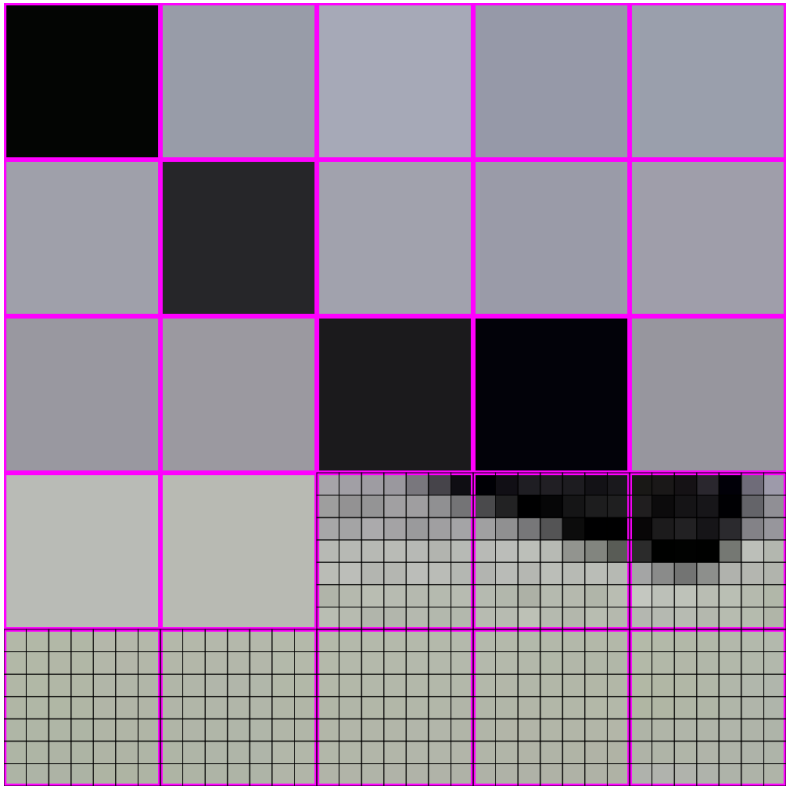

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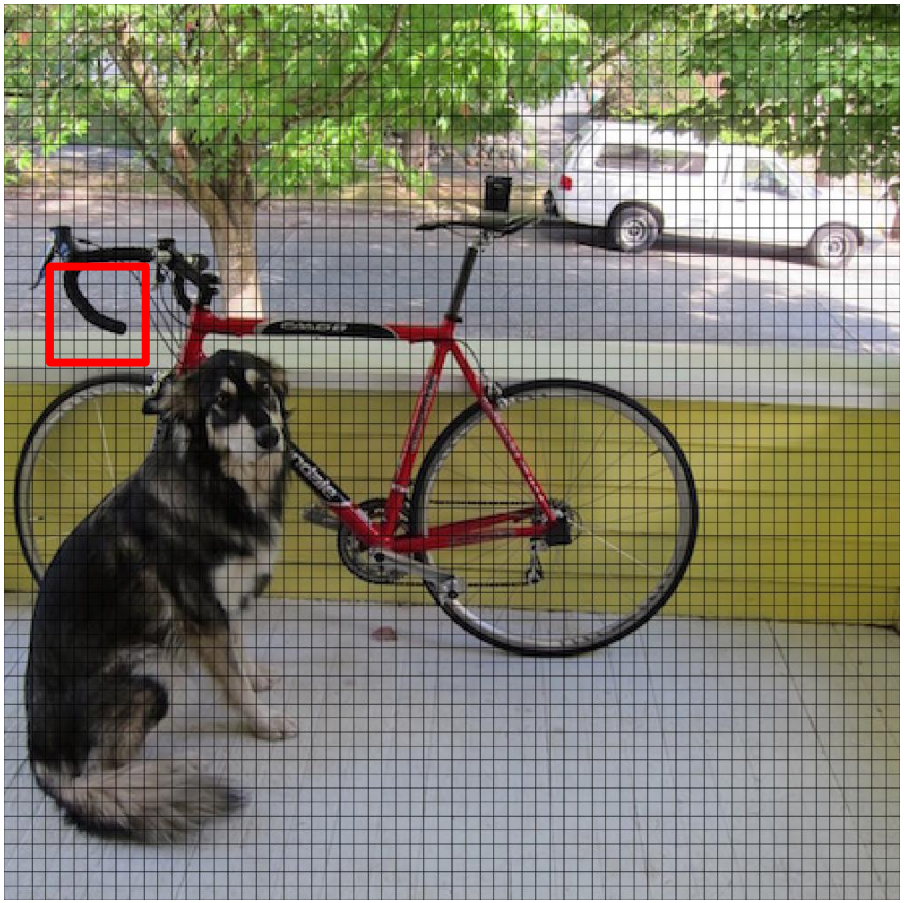

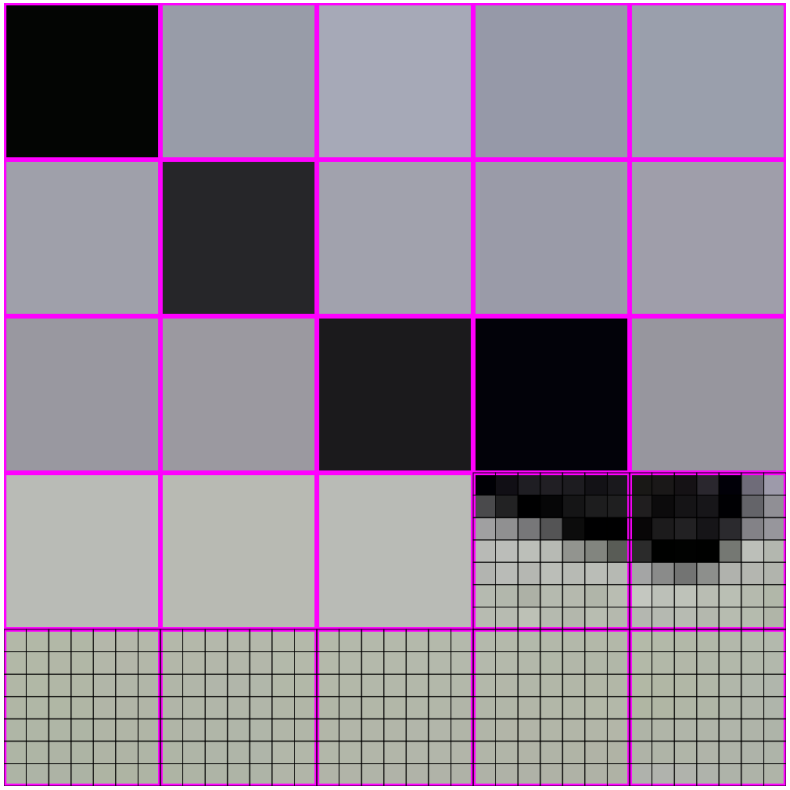

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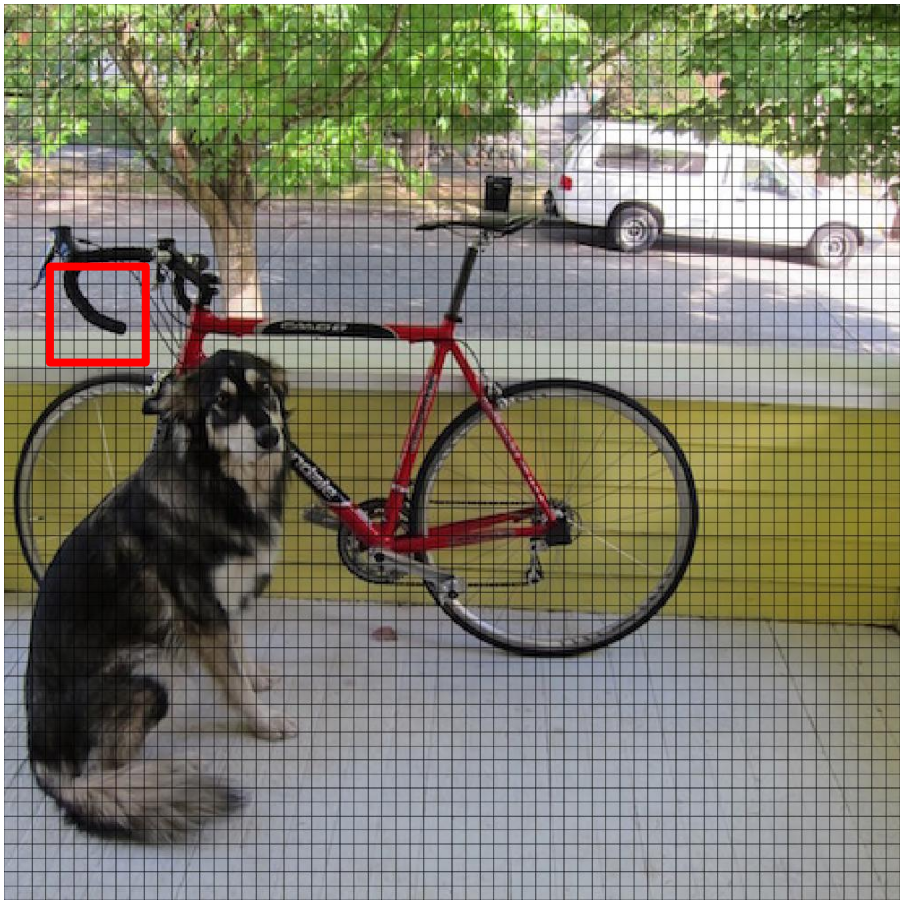

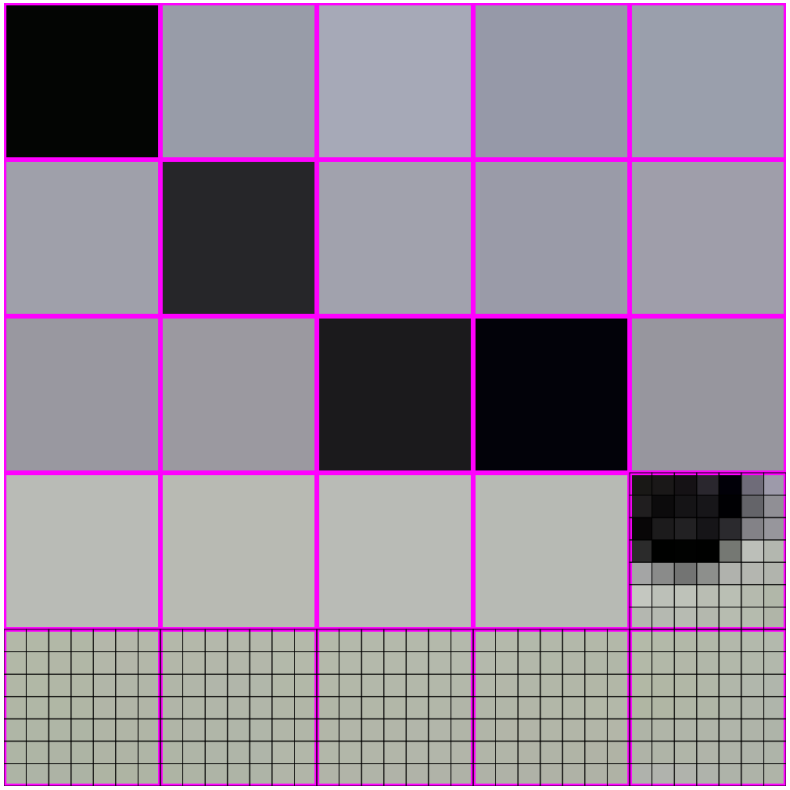

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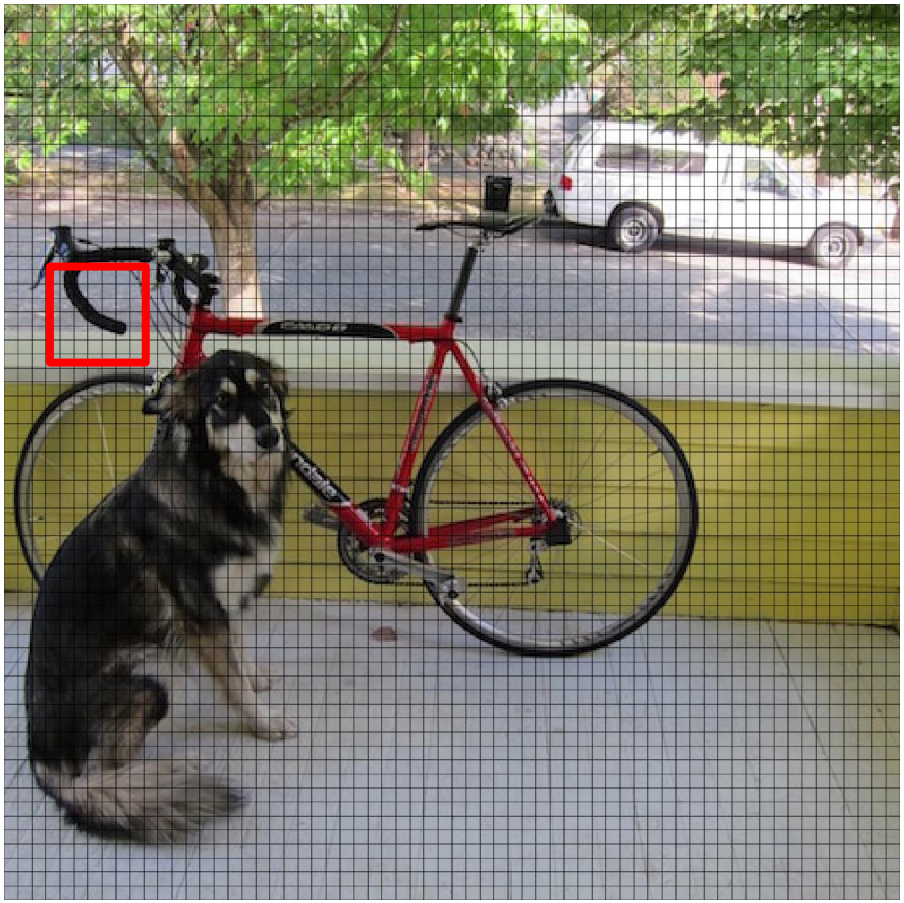

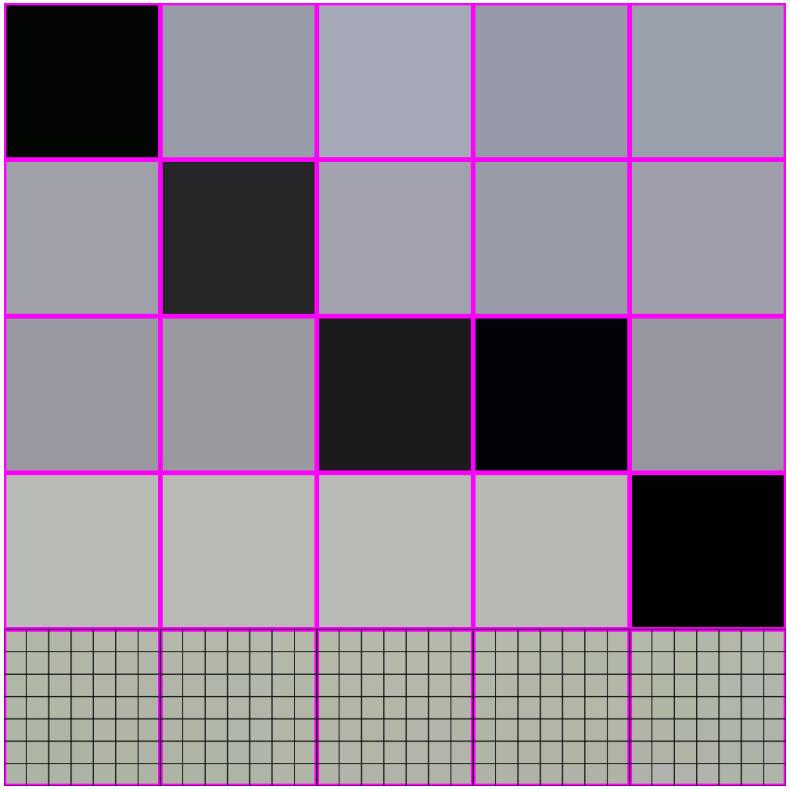

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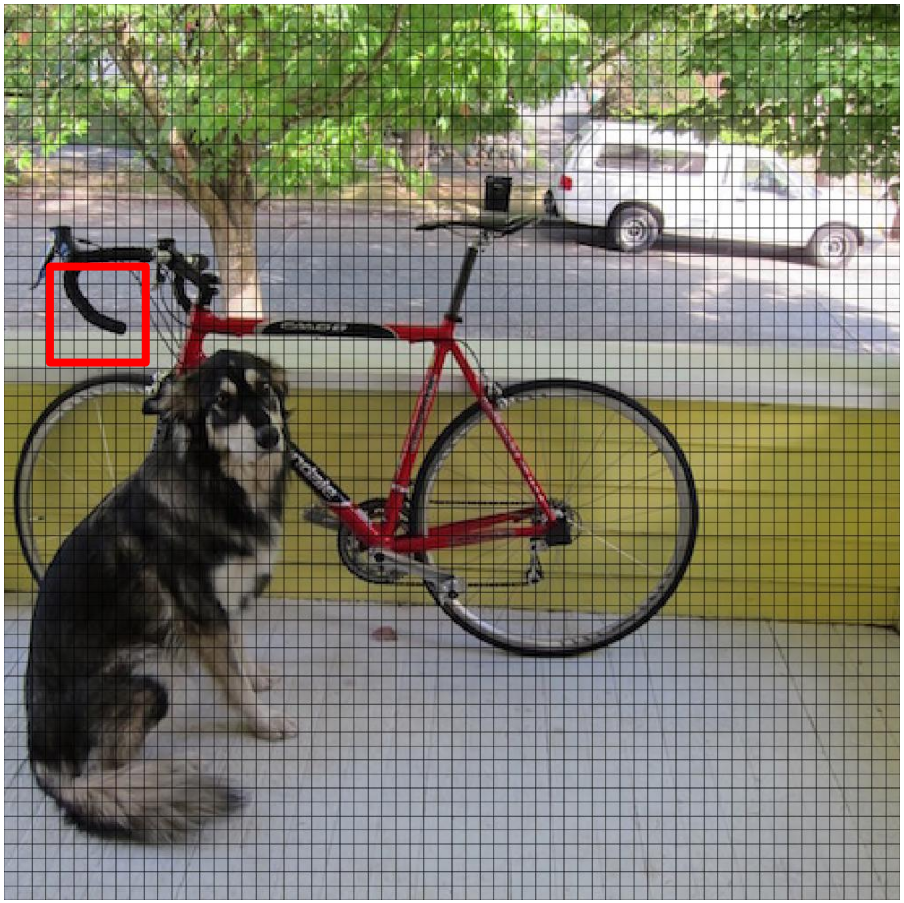

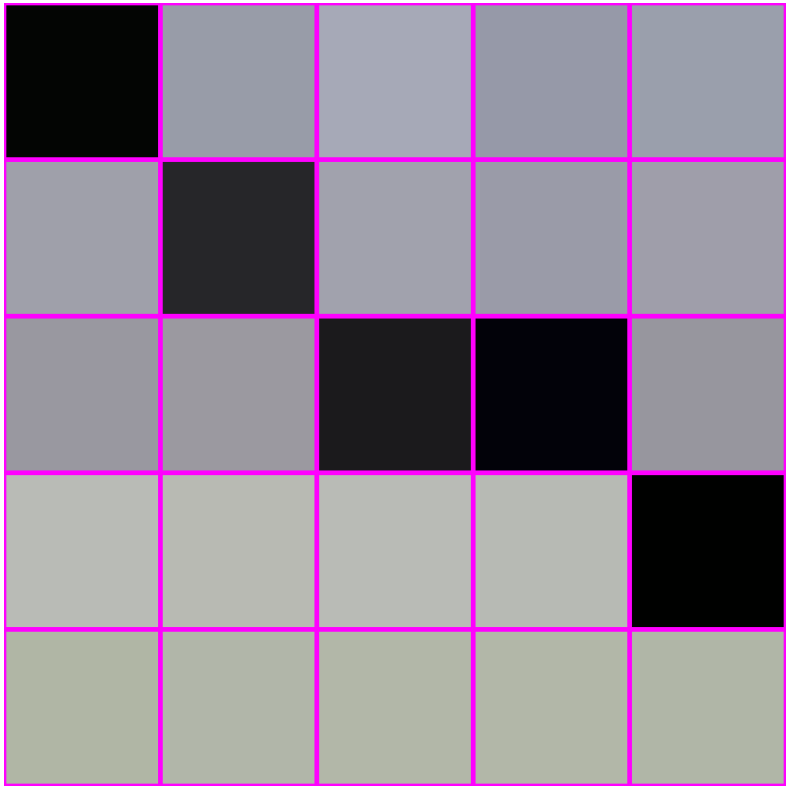

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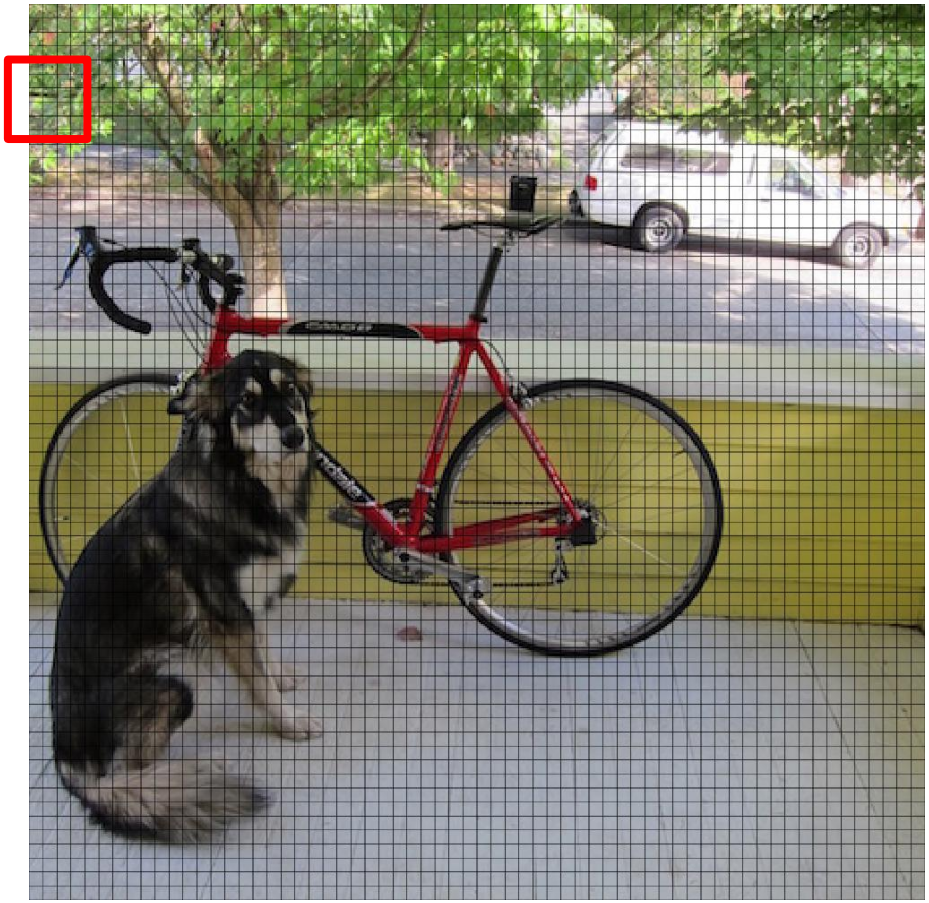

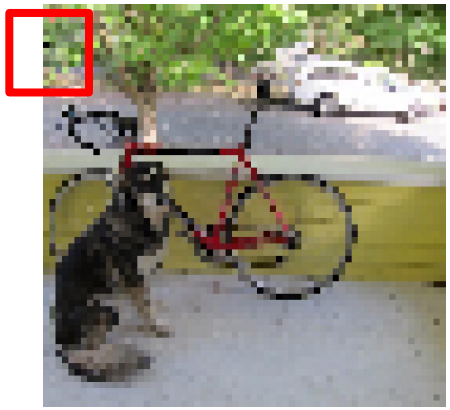

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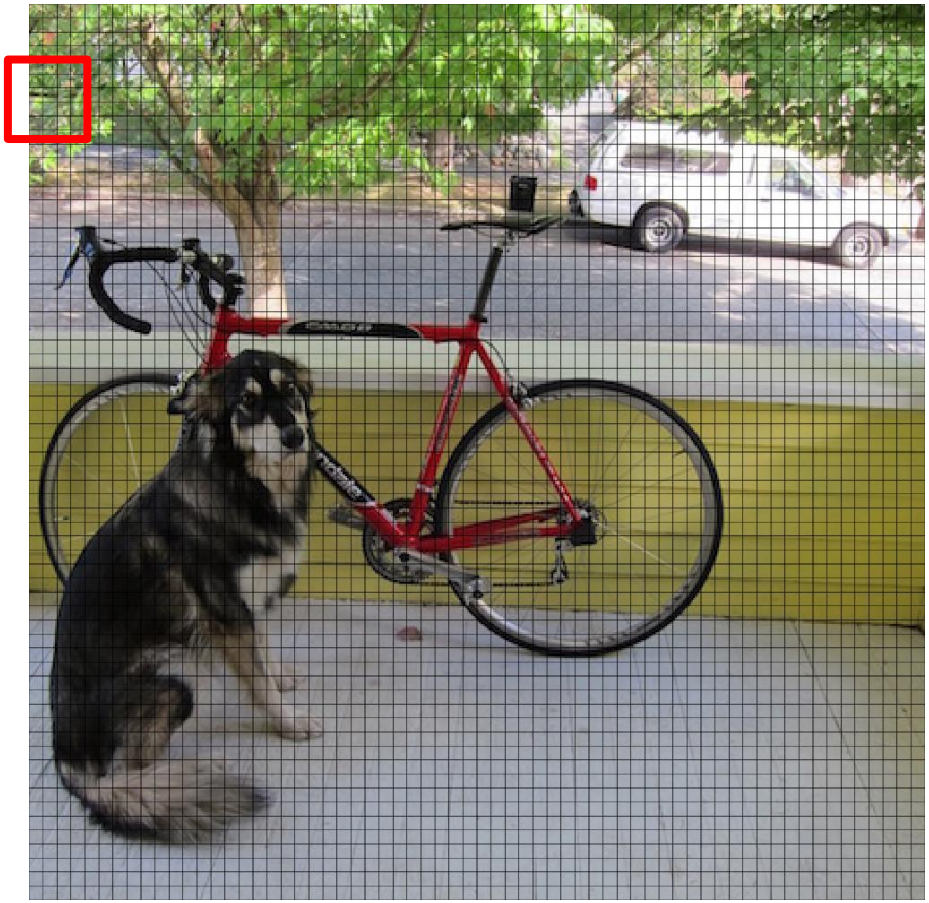

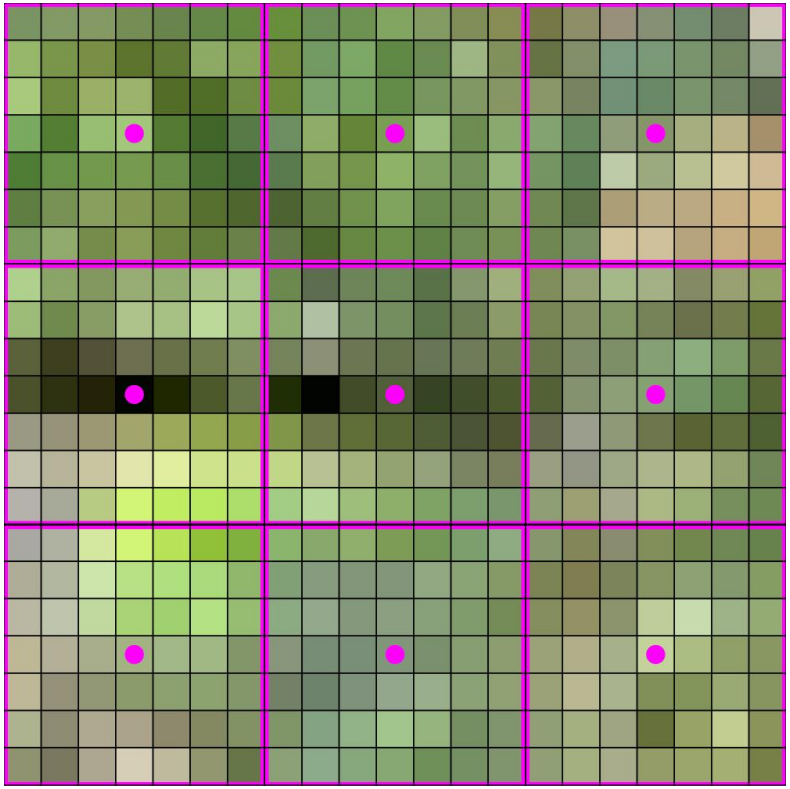

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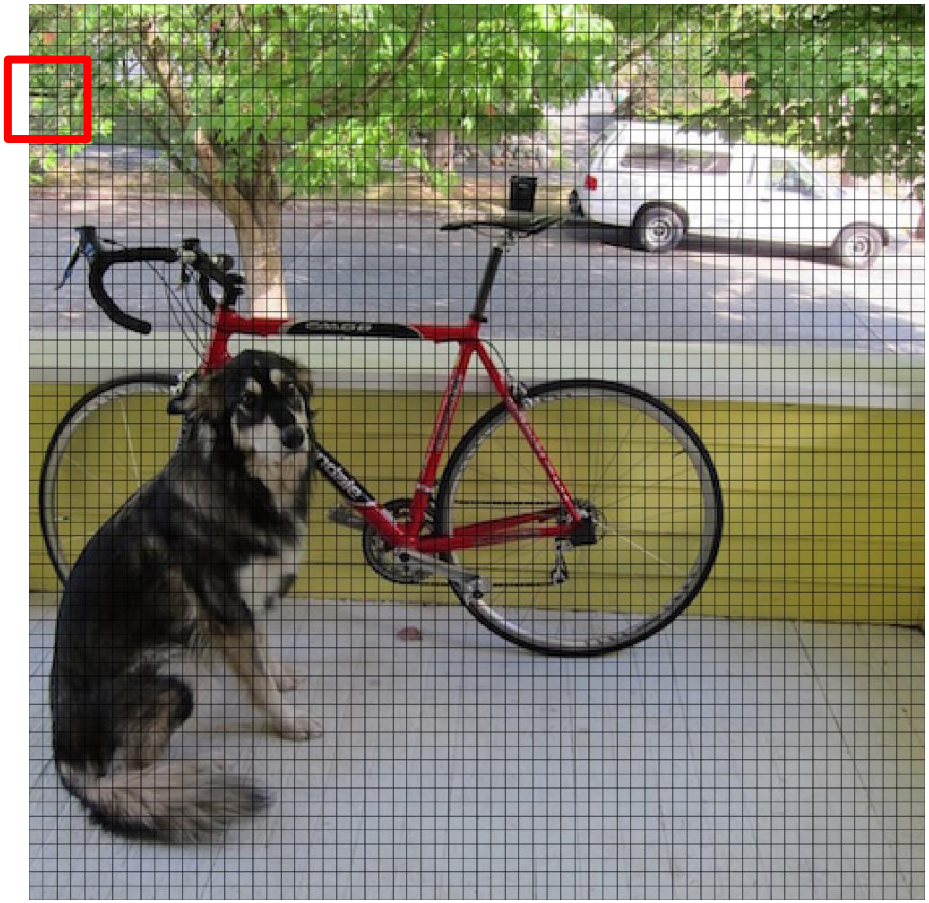
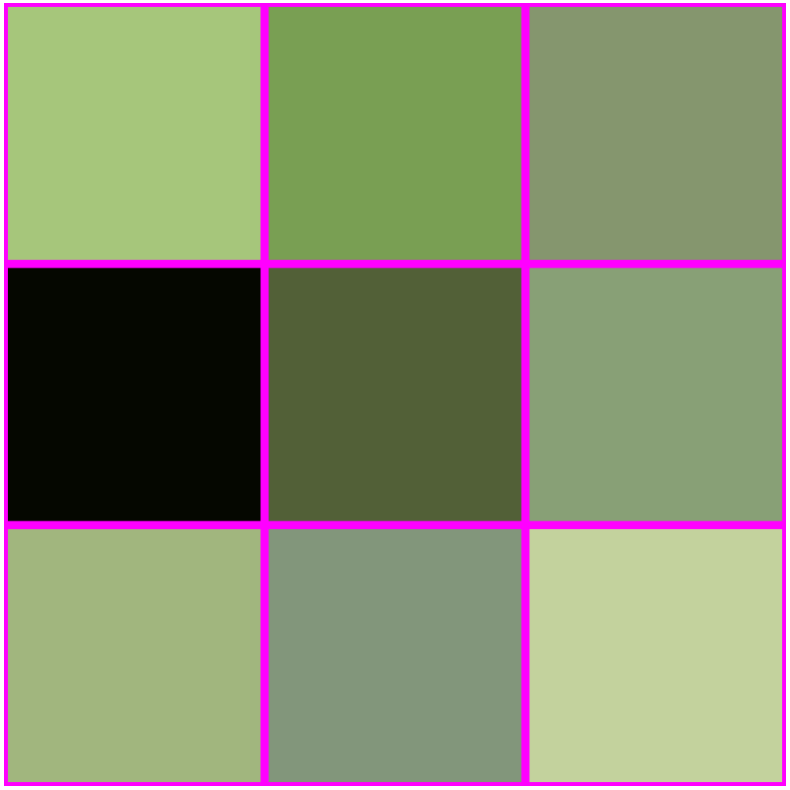
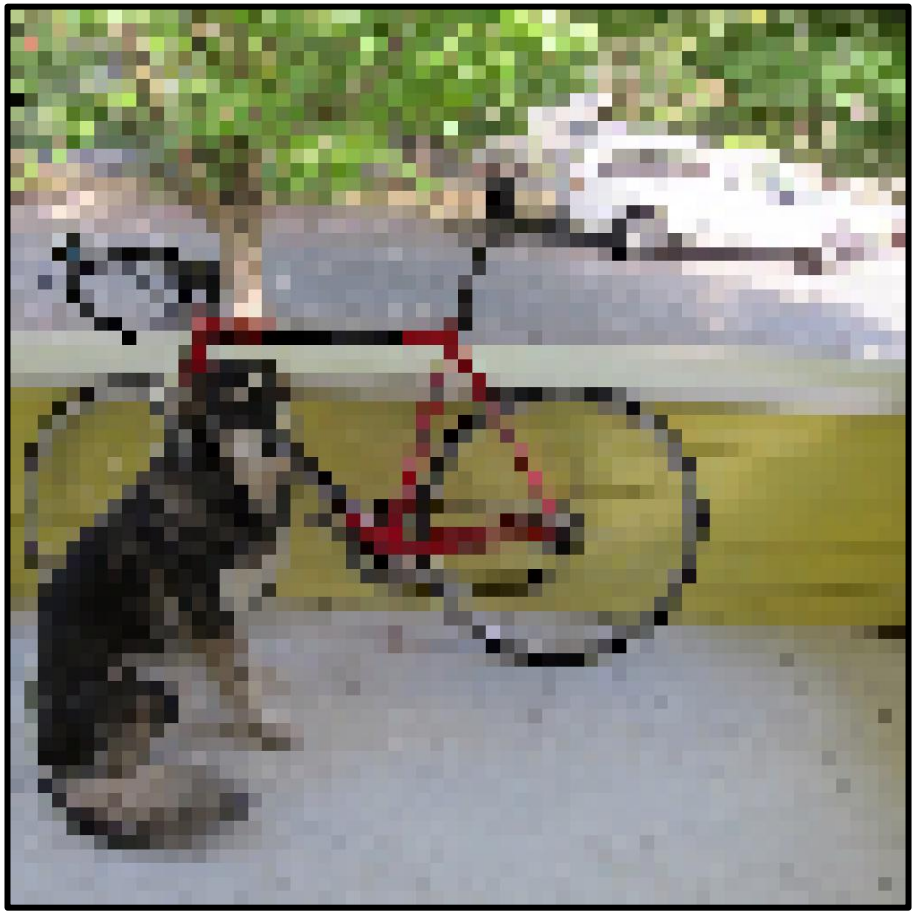




IS THIS ALL THERE IS??



THERE IS A BETTER WAY!

Next Time: Filtering