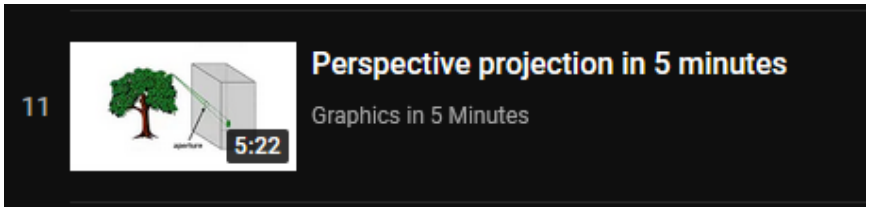
What is an image?

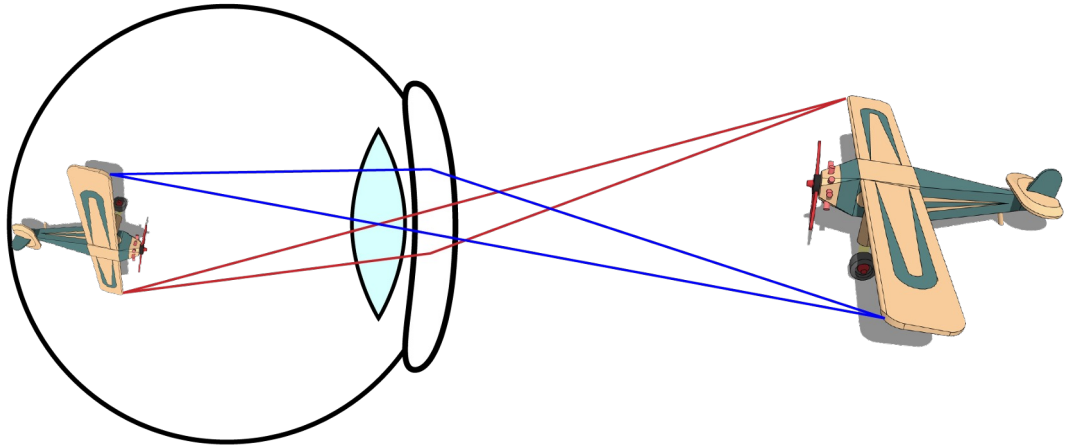
slides copied and adjusted from:
https://pjreddie.com/courses/computer-vision/

Graphics in 5 minutes

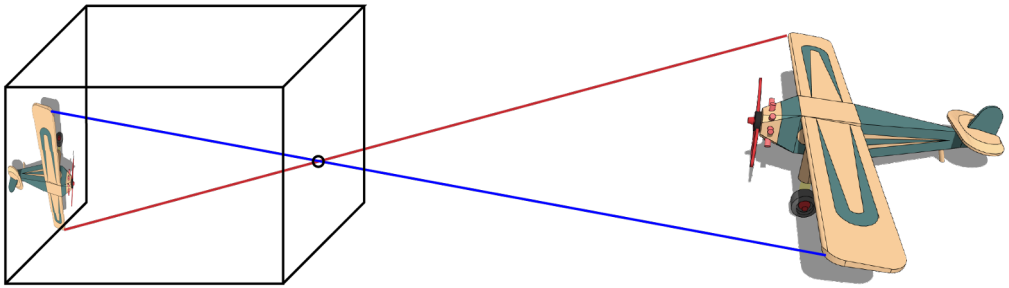
https://www.youtube.com/watch?v=F5WA26W4JaM&list=PLWfDJ5nla8UpwShx-lzLJqcp575fKpsSO&index=11



Eyes: projection onto retina



Model: pinhole camera



Model: pinhole camera

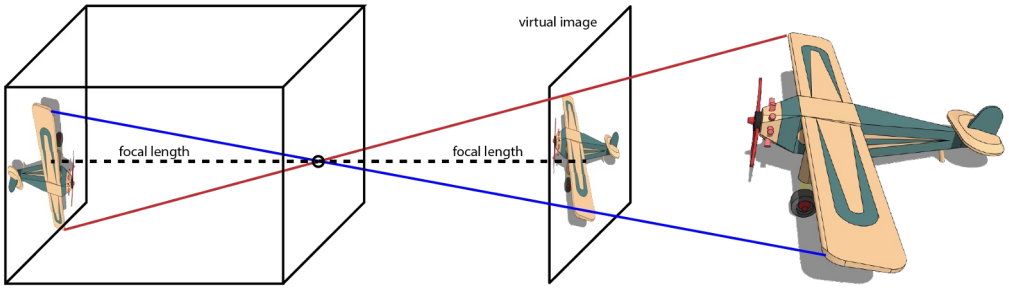


Image: 3D → 2D projection of the world

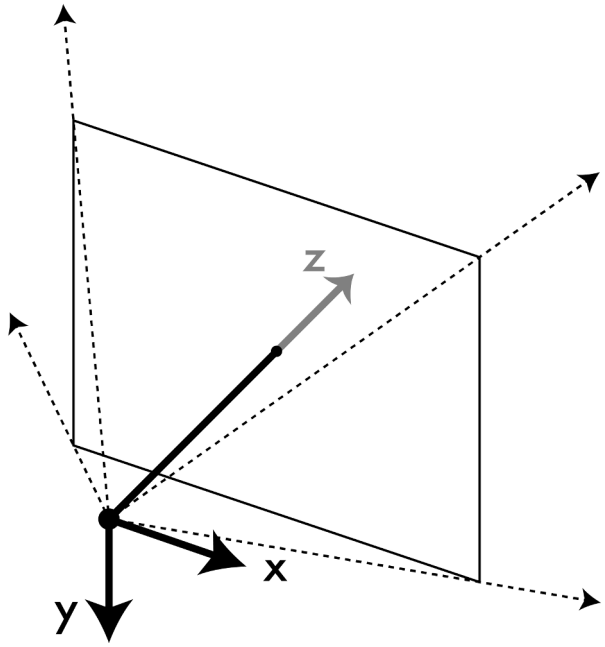


Image: 3D → 2D projection of the world

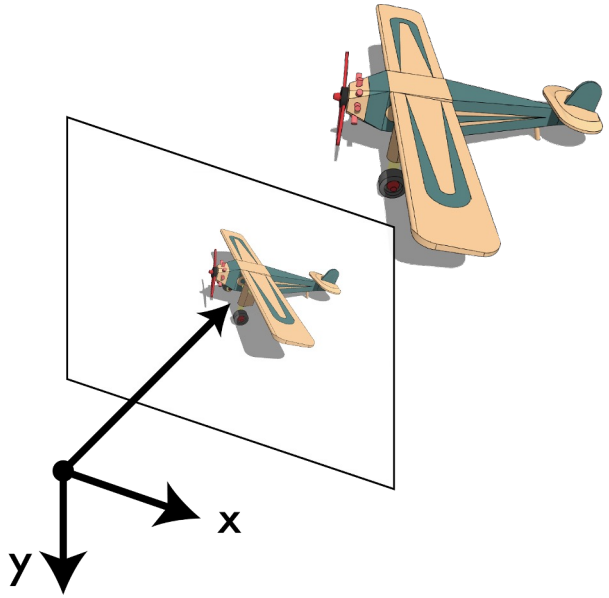


Image: 3D → 2D projection of the world

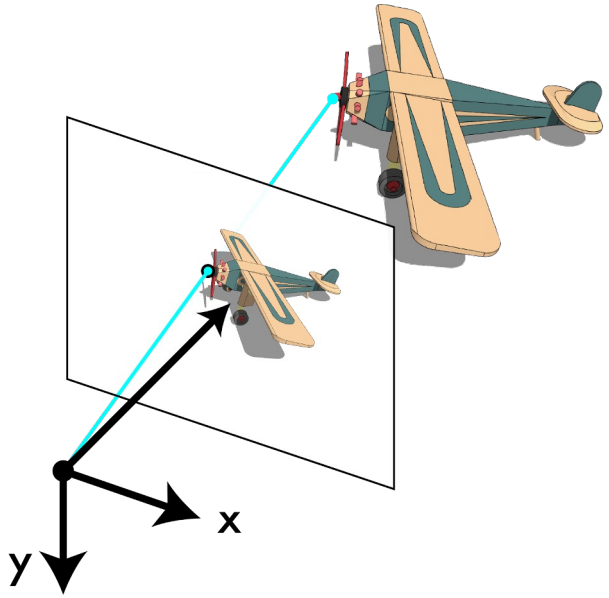


Image: 3D → 2D projection of the world

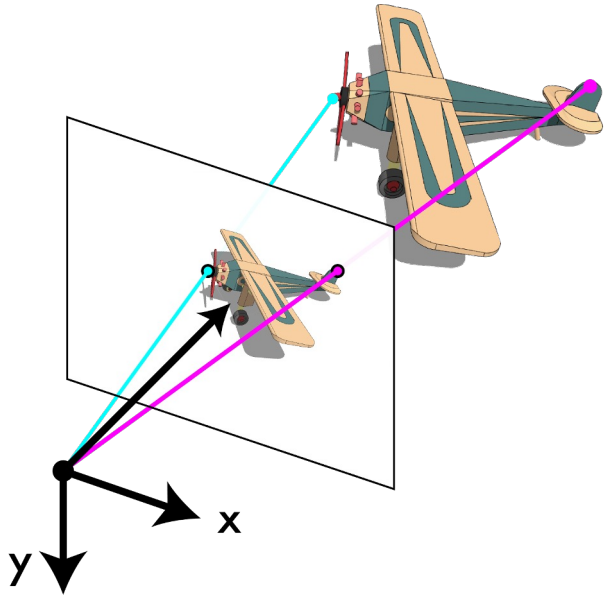


Image: 3D → 2D projection of the world

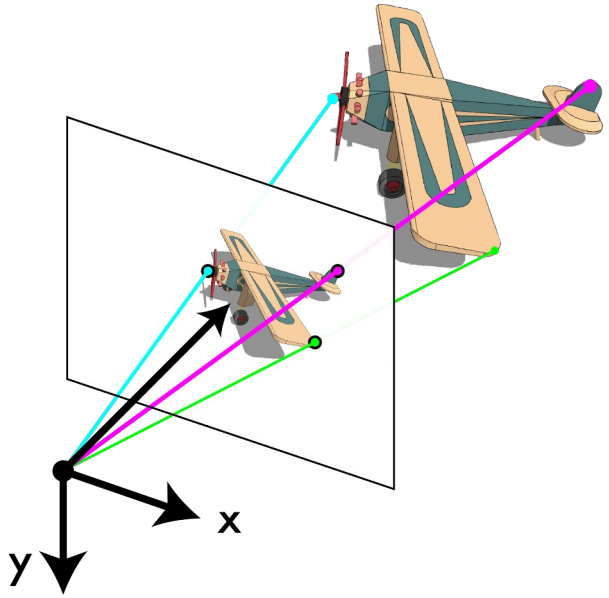
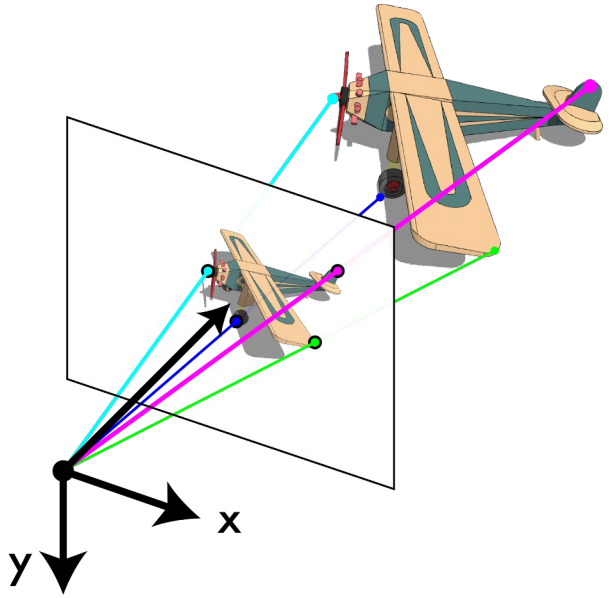
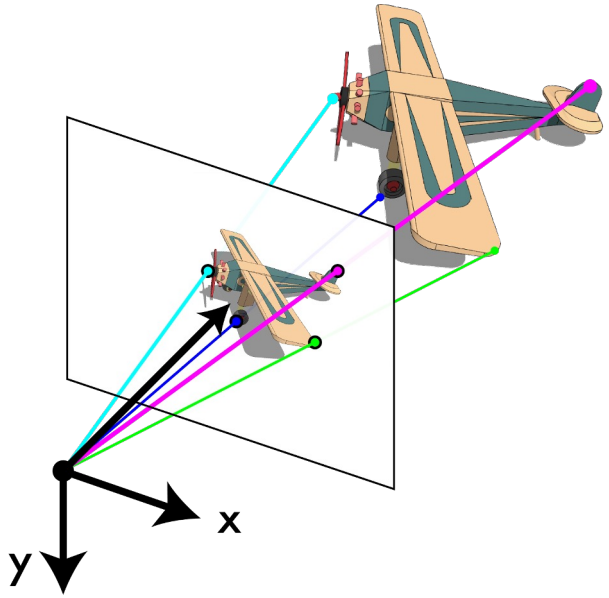


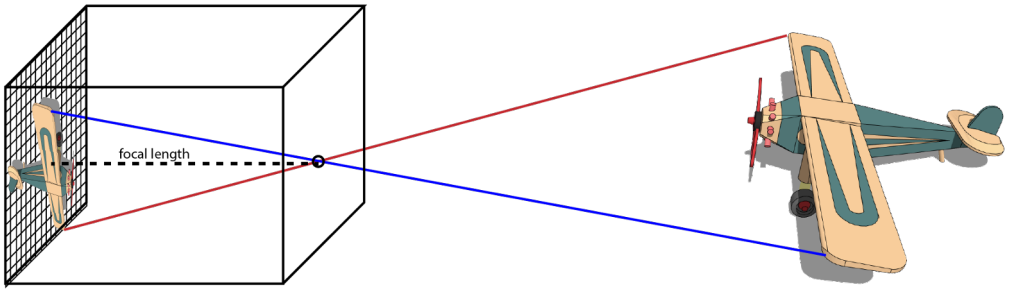
Image: 3D → 2D projection of the world



At each point we record incident light

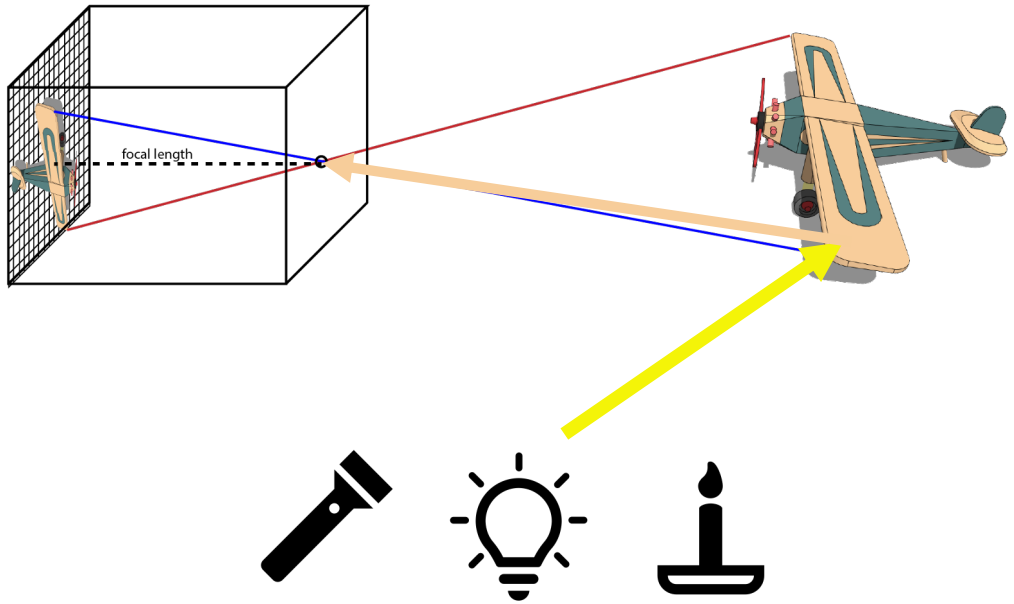


At each point we record incident light

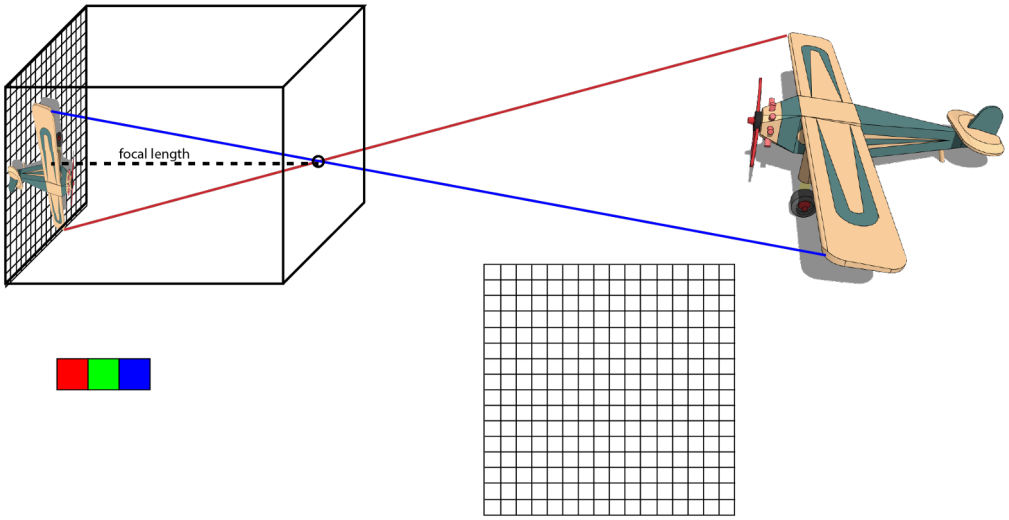


Which parameters influence the image?

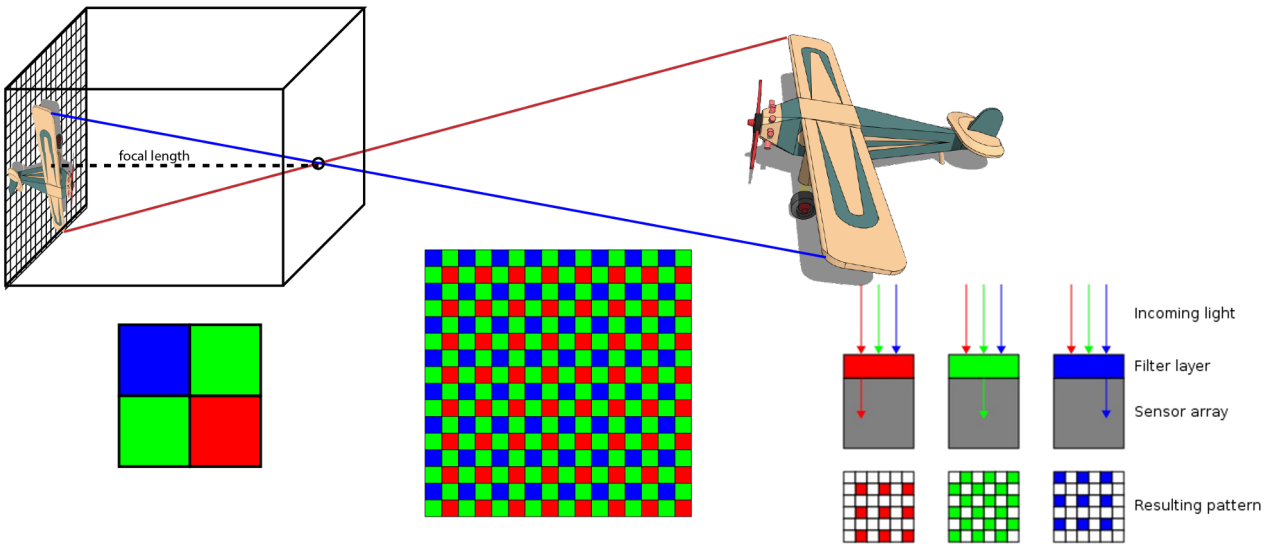
- Light sources + material of scene objects and their reflection properties.
- Geometry of scene
- Camera settings/hardware



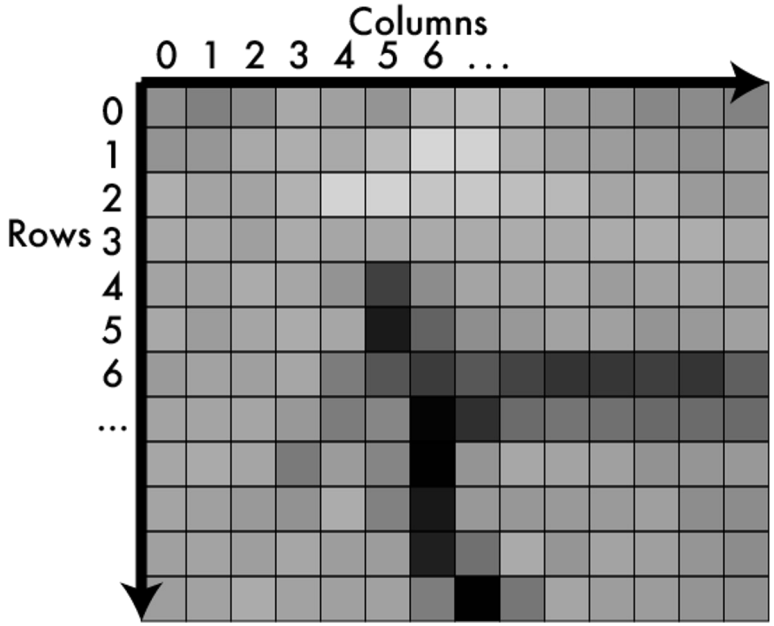
How do we record color?



Bayer pattern for CMOS sensors



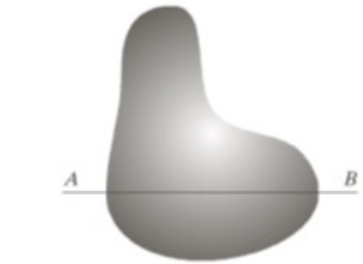
An image is a matrix of light



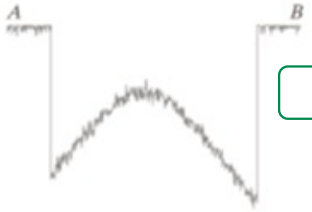
Digitalization = Sampling + Quantization

Sampling: digitizing coordinate values

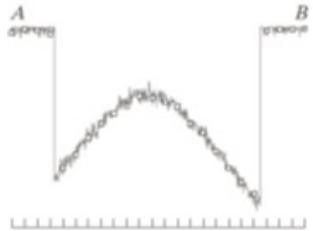
Quantization: digitizing amplitude values



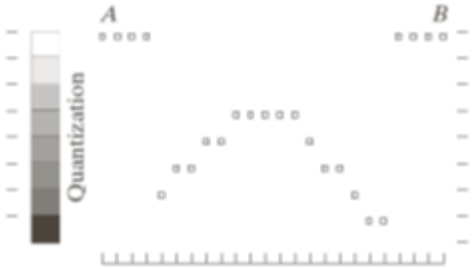
a) The scene that is captured.



b) One line (a signal)



c) Sampling (German: Abtastung)



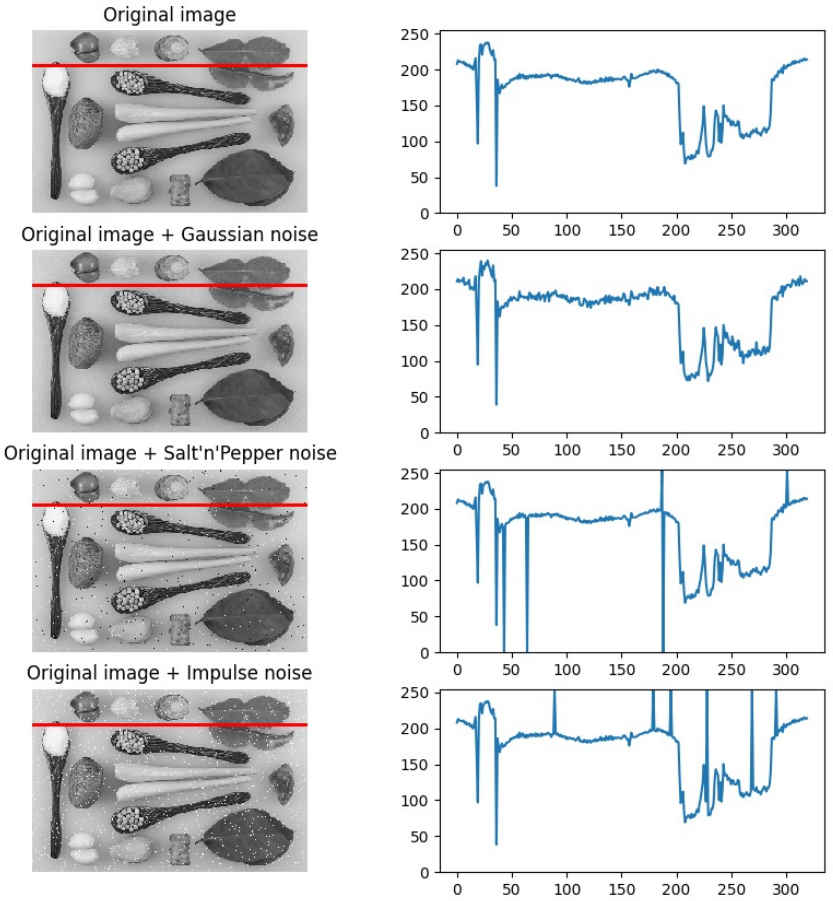
d) Quantization

a b
c d

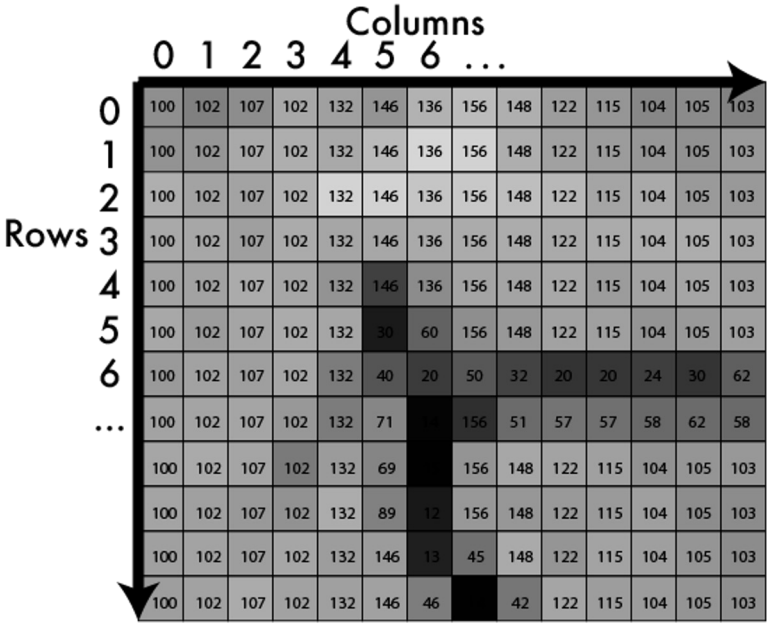
FIGURE 2.16 Generating a digital image. (a) Continuous image. (b) A scan line from *A* to *B* in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.

Image noise

- Quantization error: 8 bit grayscale is usually enough, but when compression is needed, this error becomes visible.
- Gaussian noise: Intensity fluctuations originating from a Gaussian normal distribution
- Impulse noise: Random occurrence of black and white pixels (aka salt and pepper noise)
- See Wikipedia for details.



Values in matrix = how much light



Values in matrix = how much light

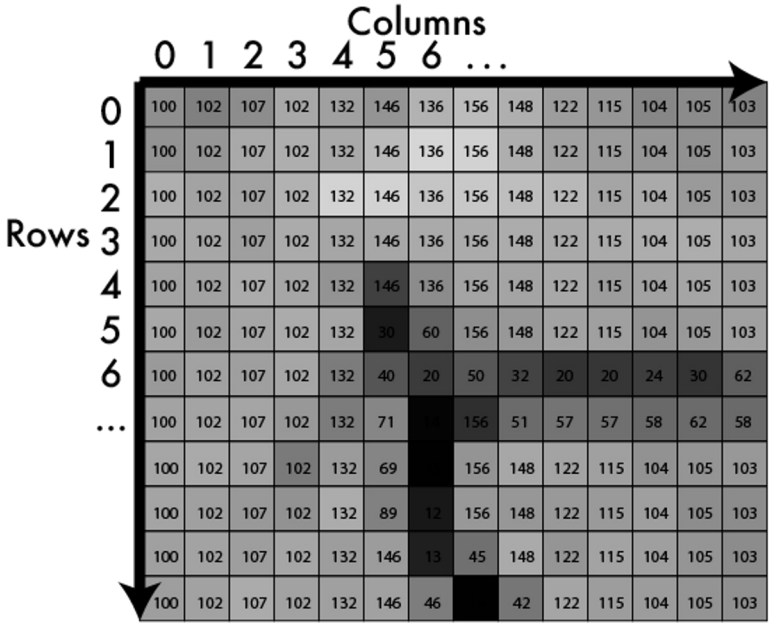
Higher = more light

Lower = less light

Bounded

- No light = 0
- Sensor/device limit = max
- Typical ranges:
  - [0-255] → fits into byte
  - [0-1] → as floating point

Called “pixels”



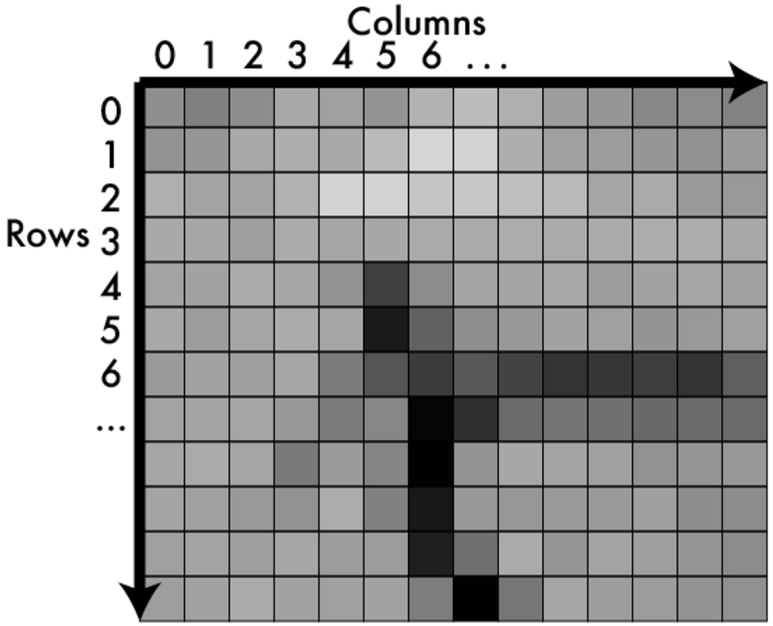
Addressing pixels

Ways to index:

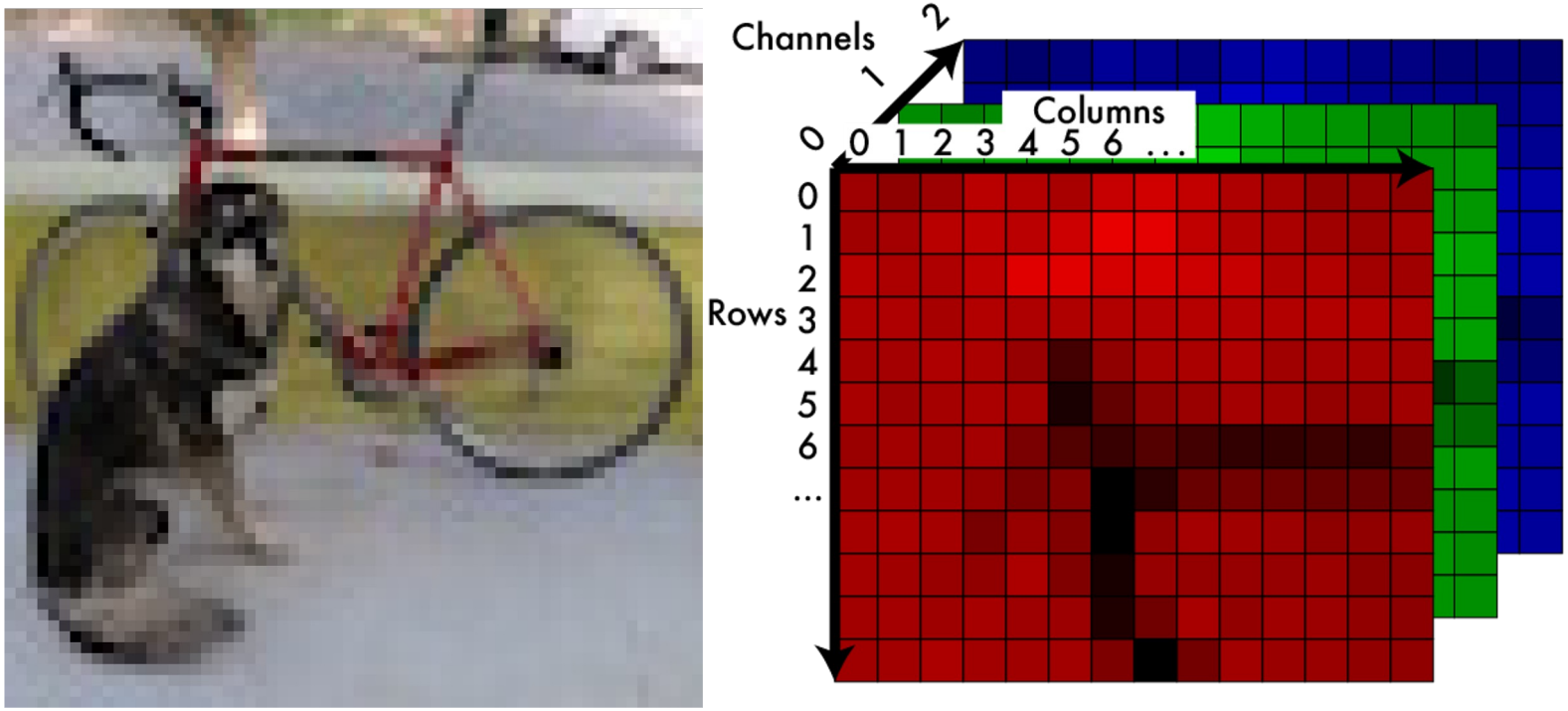
- (x,y)
  - Like cartesian coordinates
  - (3,6) is column 3 row 6
- (r,c) or (i,j)
  - Like matrix notation
  - (3,6) is row 3 column 6

For your future:

- Arbitrary
- Only thing that matters is consistency



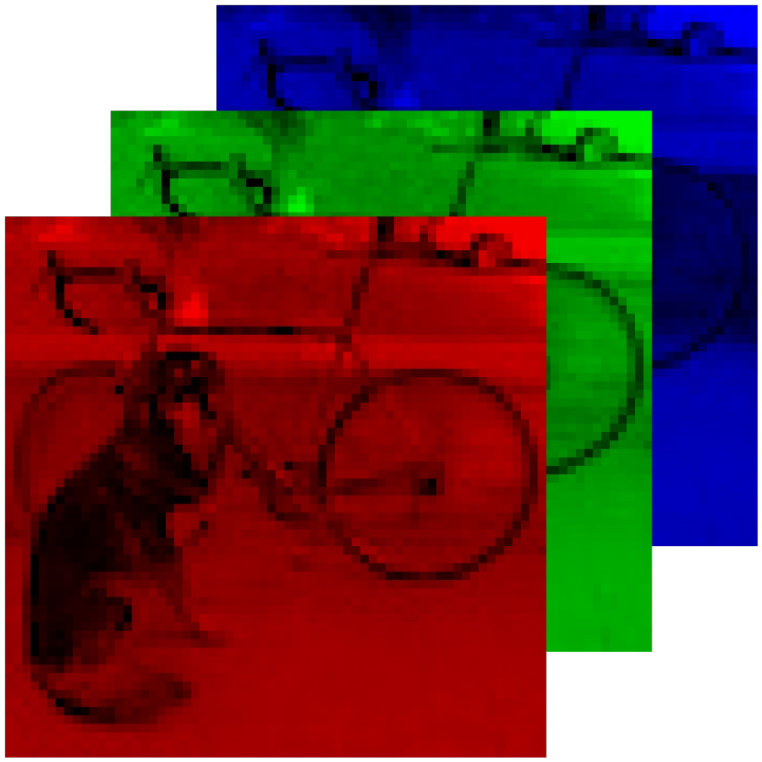
Color image: 3D tensor in colorspace



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

If you use (x,y,c)

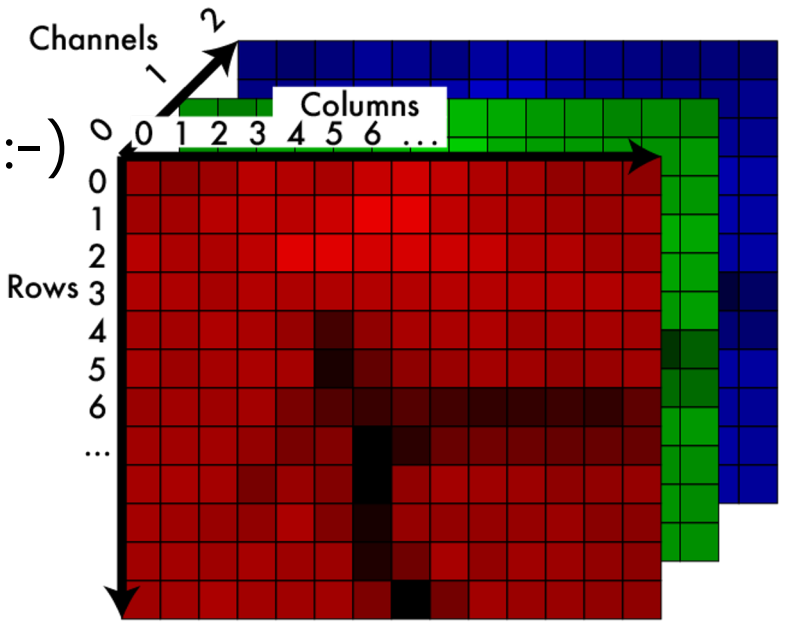
- (1,2,0):
  - column 1, row 2, channel 0

Still doesn't matter, just be consistent

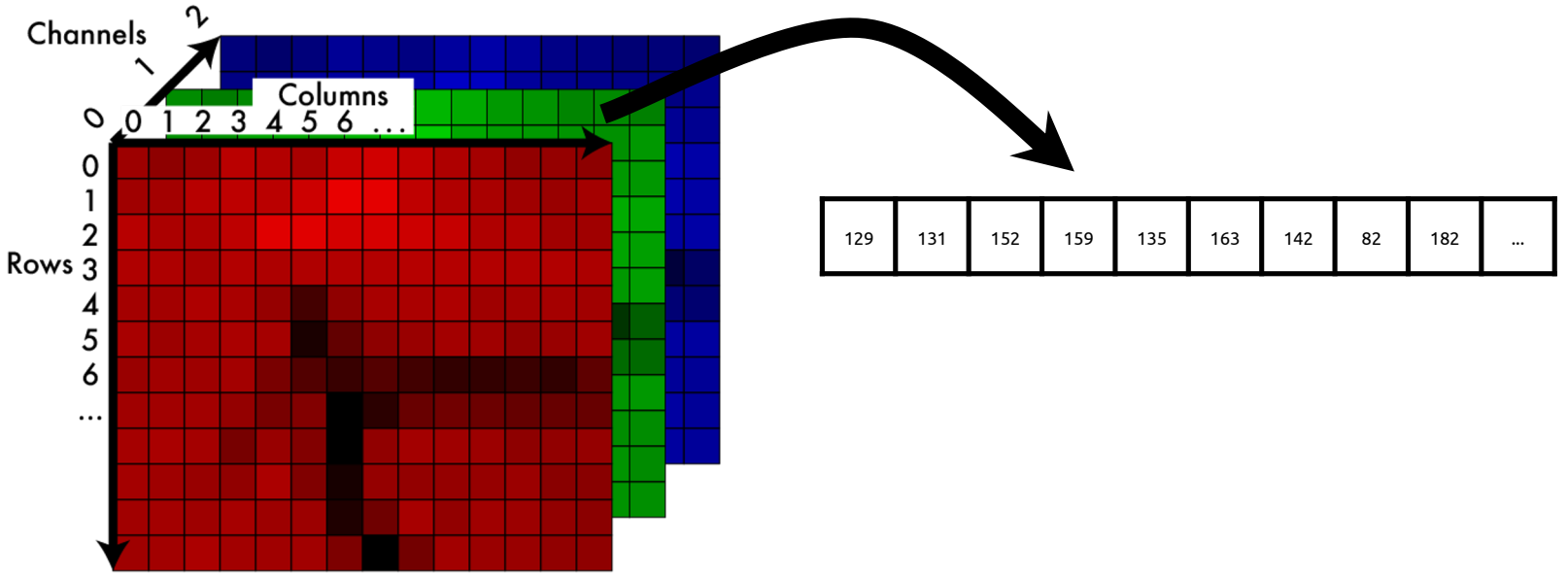
But know what you do for homeworks :-)

Also for size:

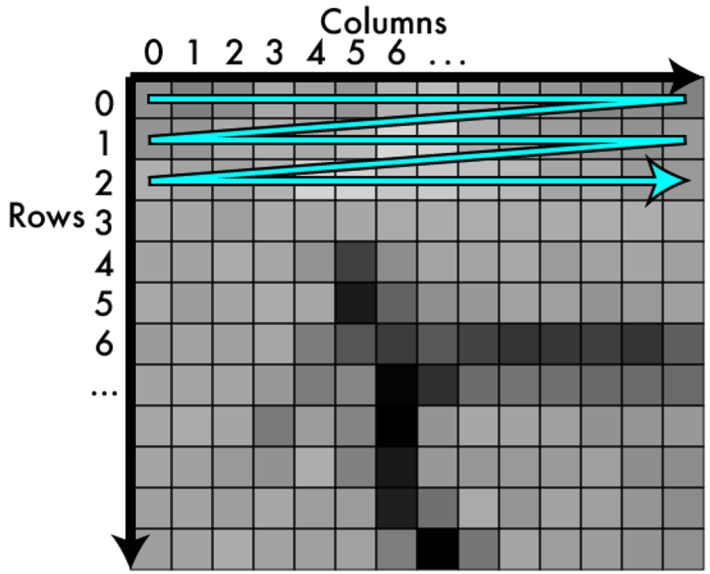
- 1920 x 1080 x 3 image:
  - 1920 px wide (width)
  - 1080 px tall (height)
  - 3 channels

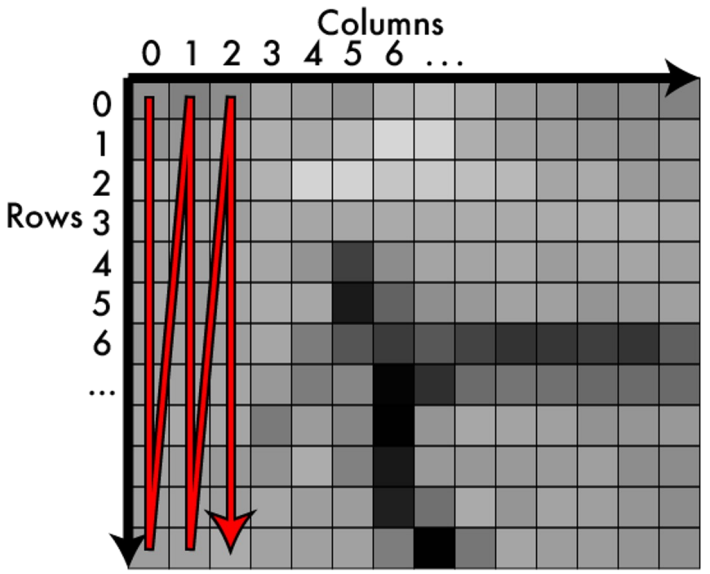


How do we store them?



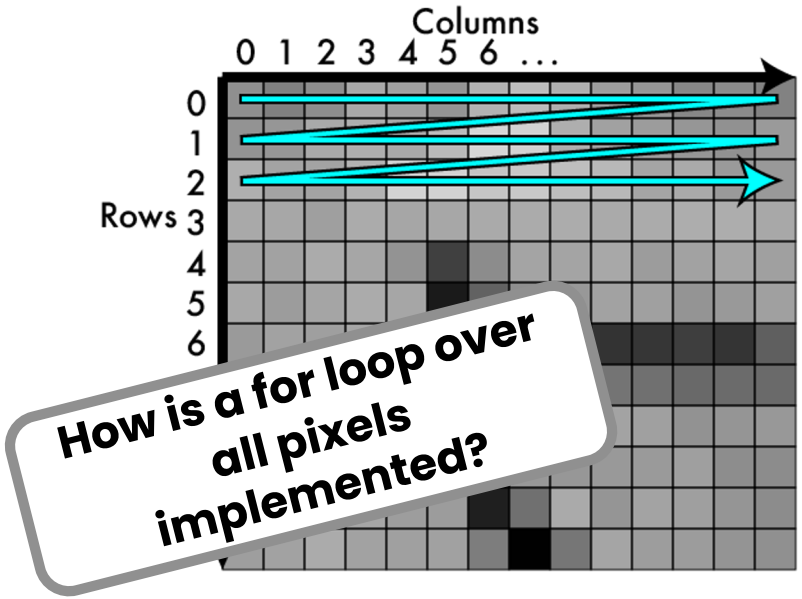
Storage: row major vs column major

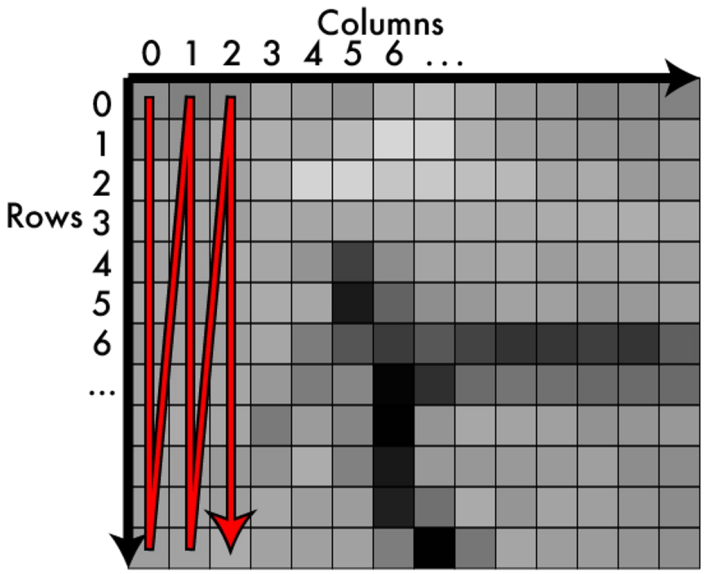




For loop quiz

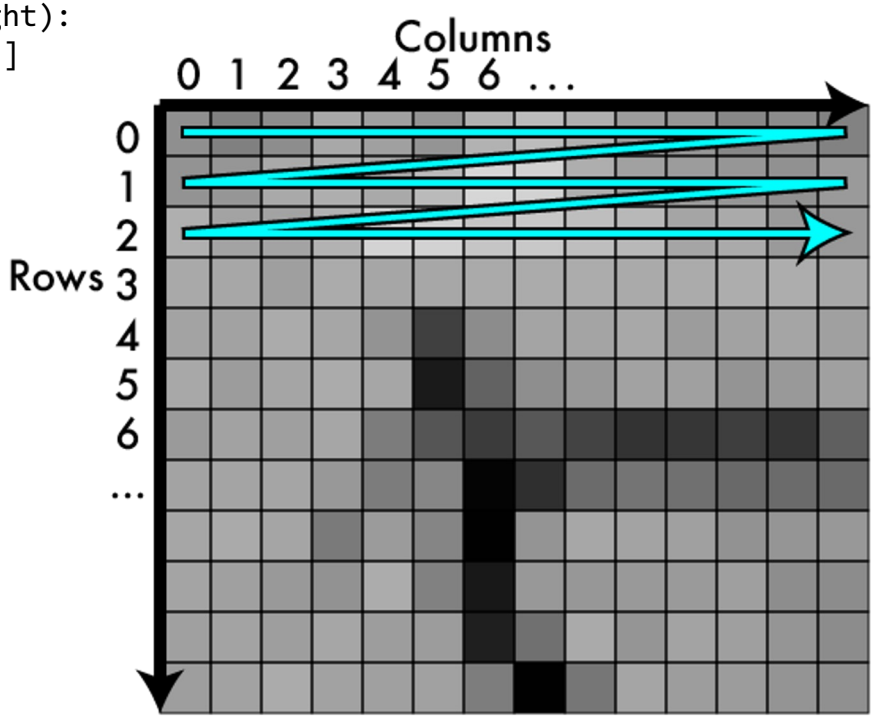
NumPy creates arrays in row-major order by default.



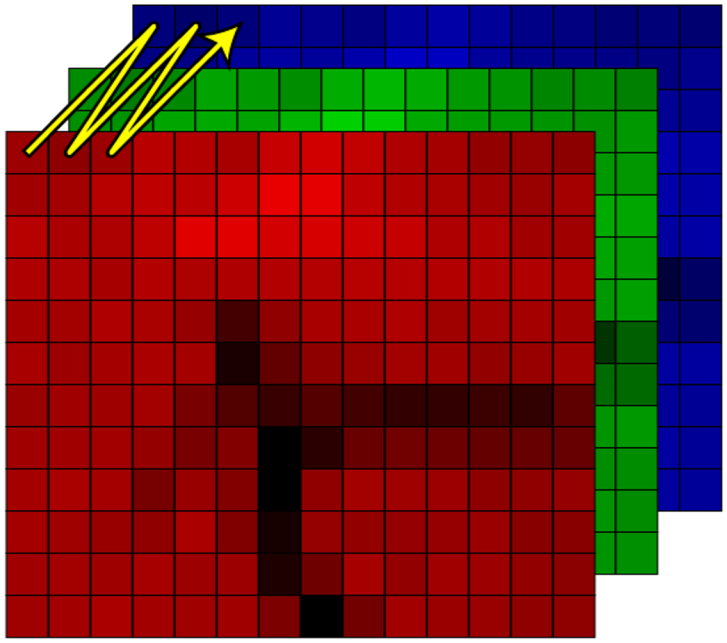


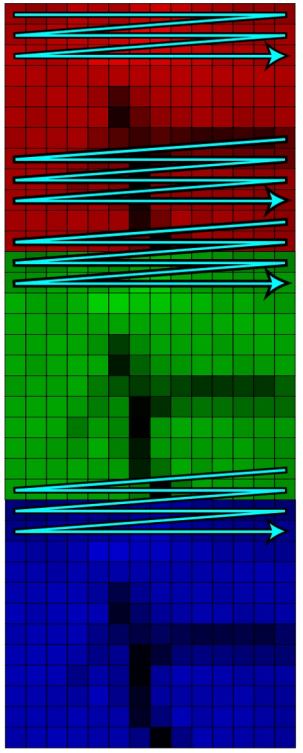
NumPy creates arrays in row-major order by default.

```
for i in range(width*height):
    curr_pix = img.flat[i]
```



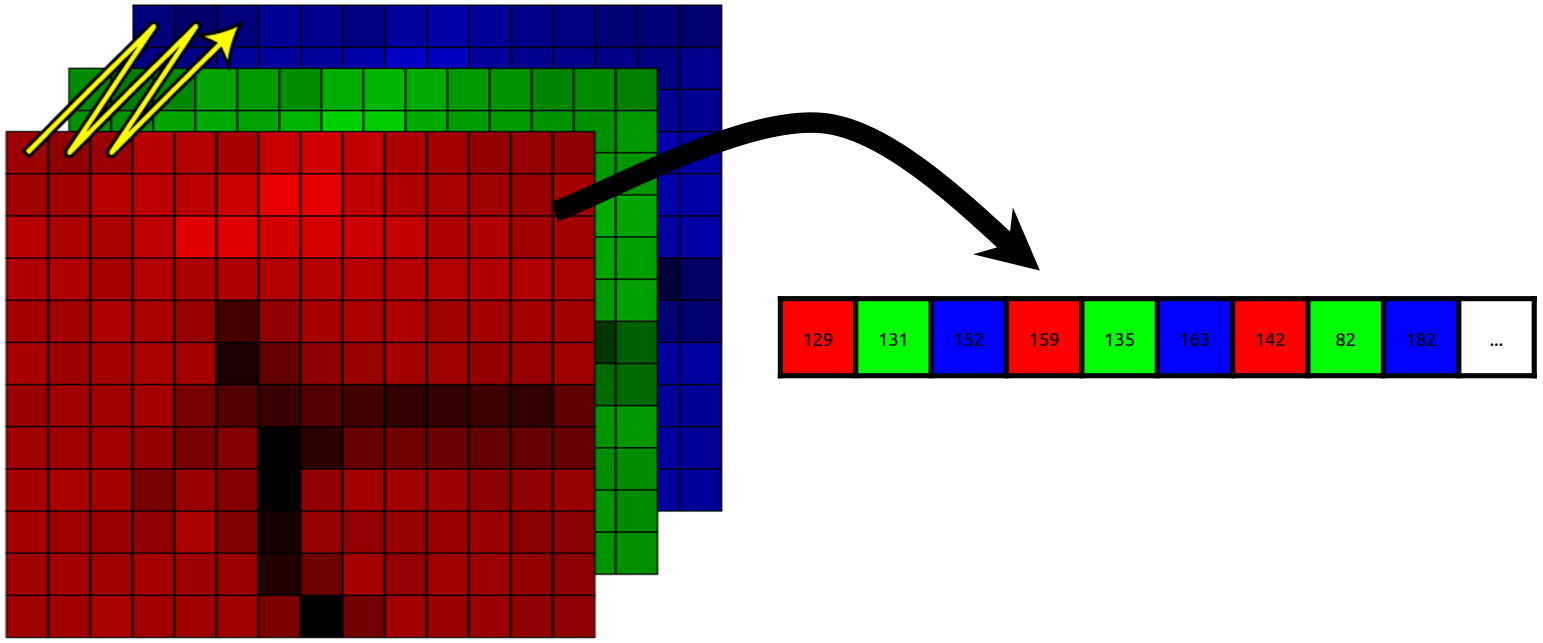
In 3D we have more choices!



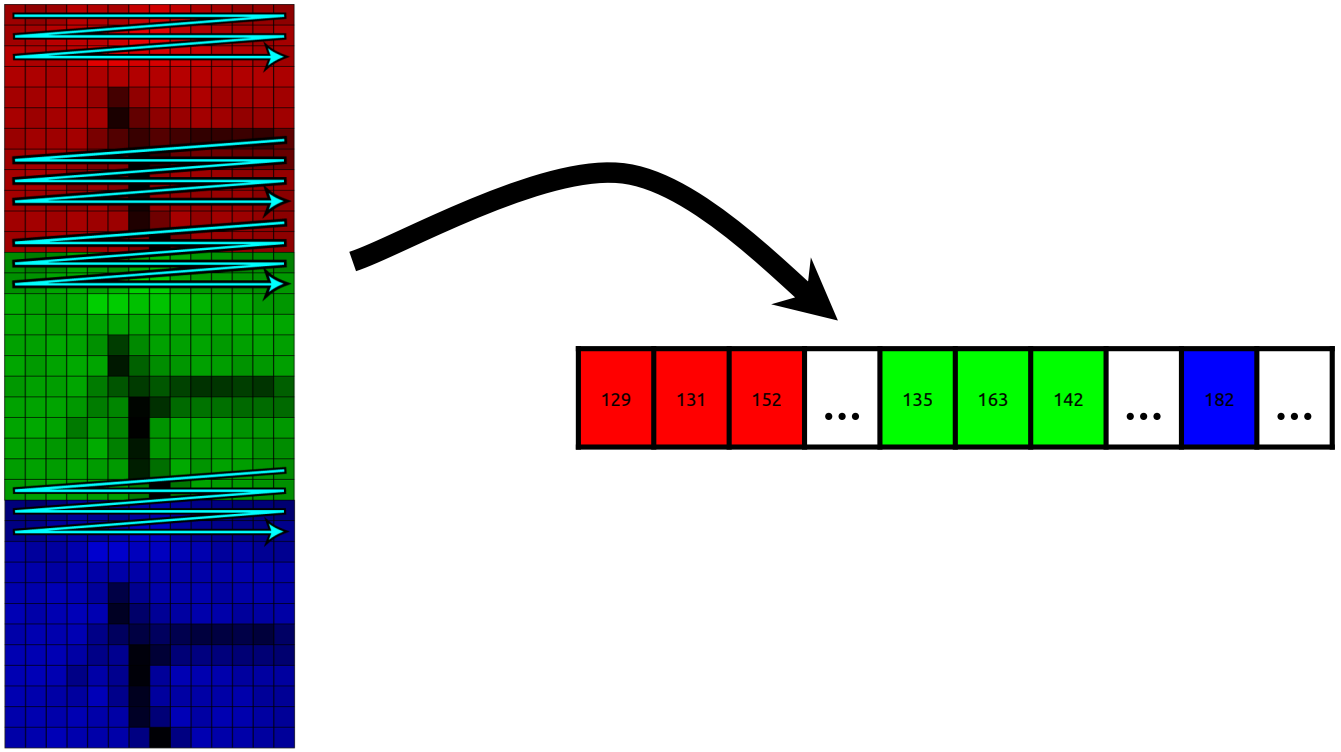


HWC: channels interleaved

```
for i in range(width*height*channels):
    curr_pix = img.flat[i]
```



CHW: channels separated



Numpy quiz

```
print(img.shape)
>>> (200, 280, 3)

# set some area of the image to zero
x = 200
y = 40
c = 1
img[y:y+20, x:x+20, c] = 0
```

How does the resulting image look like?

Further reading

If you want to know more about cameras and go much deeper, check out this:

ICCV 2023 Tutorial on

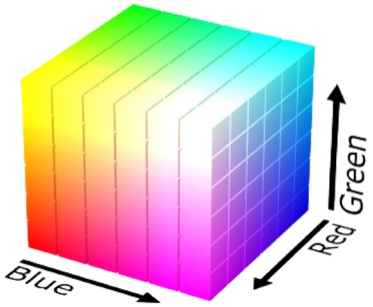
Understanding the In-Camera Rendering Pipeline and the role of AI/Deep Learning

Oct 3, 2023 (Tuesday, Half Day Tutorial - PM)
Instructor
Michael S. Brown
Professor and Canada Research Chair
York University, Canada

Senior Director, Samsung AI Center
Toronto, Canada

https://www.eecs.yorku.ca/~mbrown/ICCV2023_Brown.html

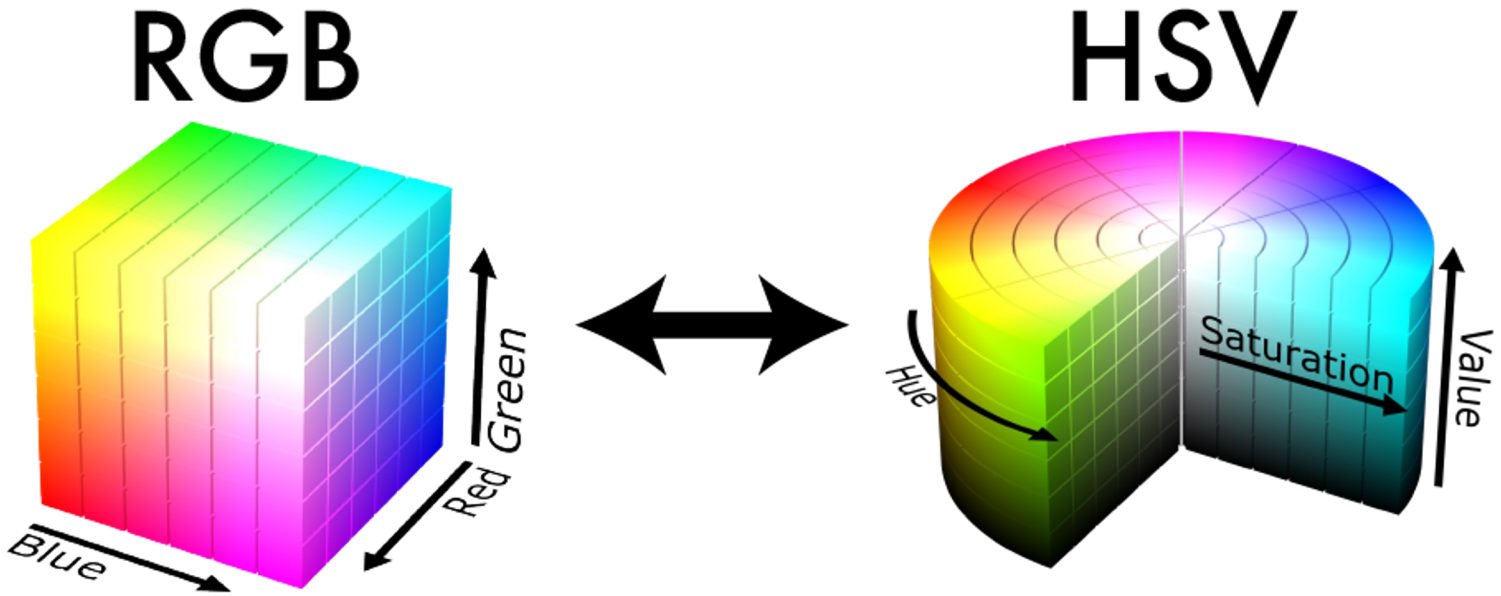
Farbräume



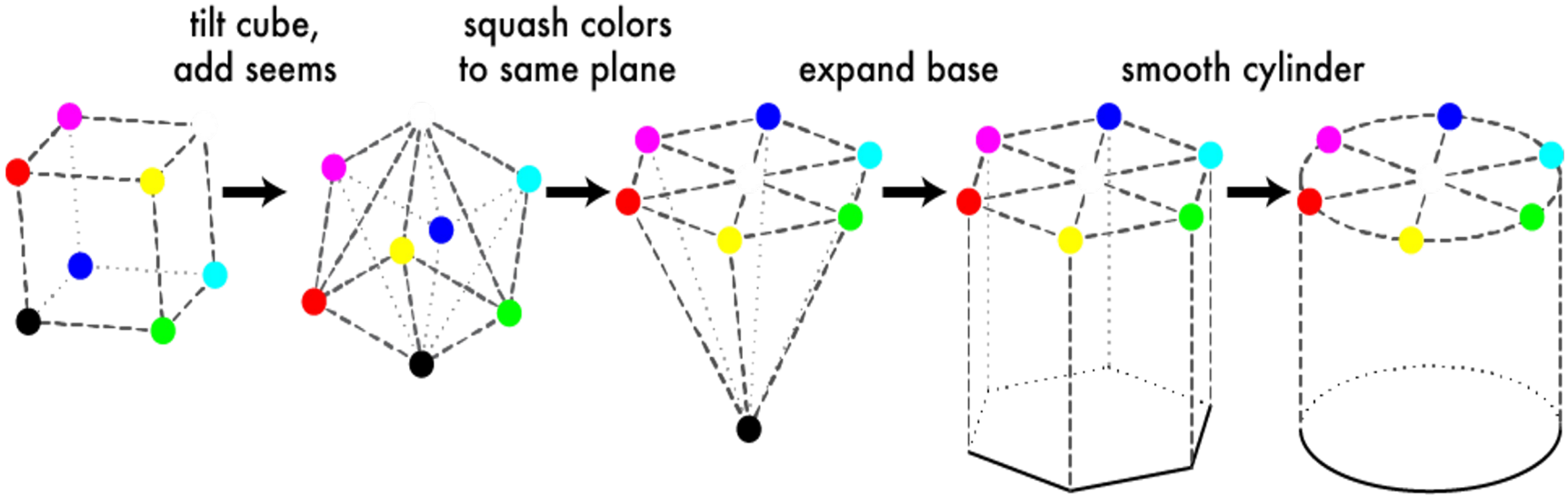
What is a color space?

Slides are from:
https://pjreddie.com/courses/computer-vision/

Other colorspaces are fun!

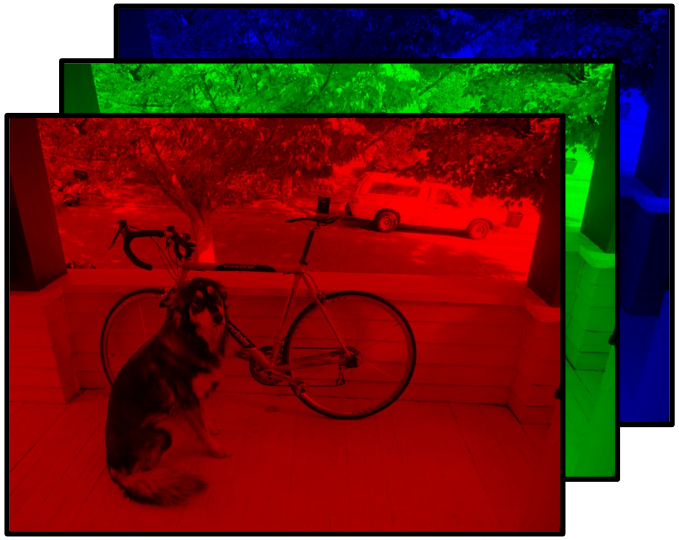


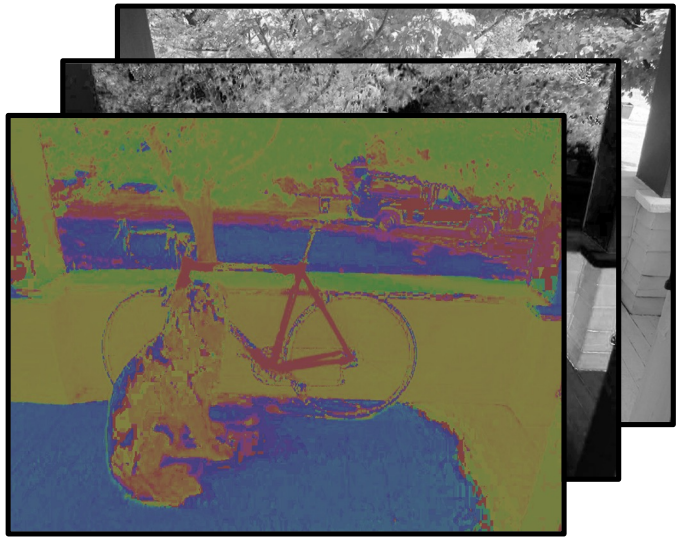
Geometric HSV to RGB:



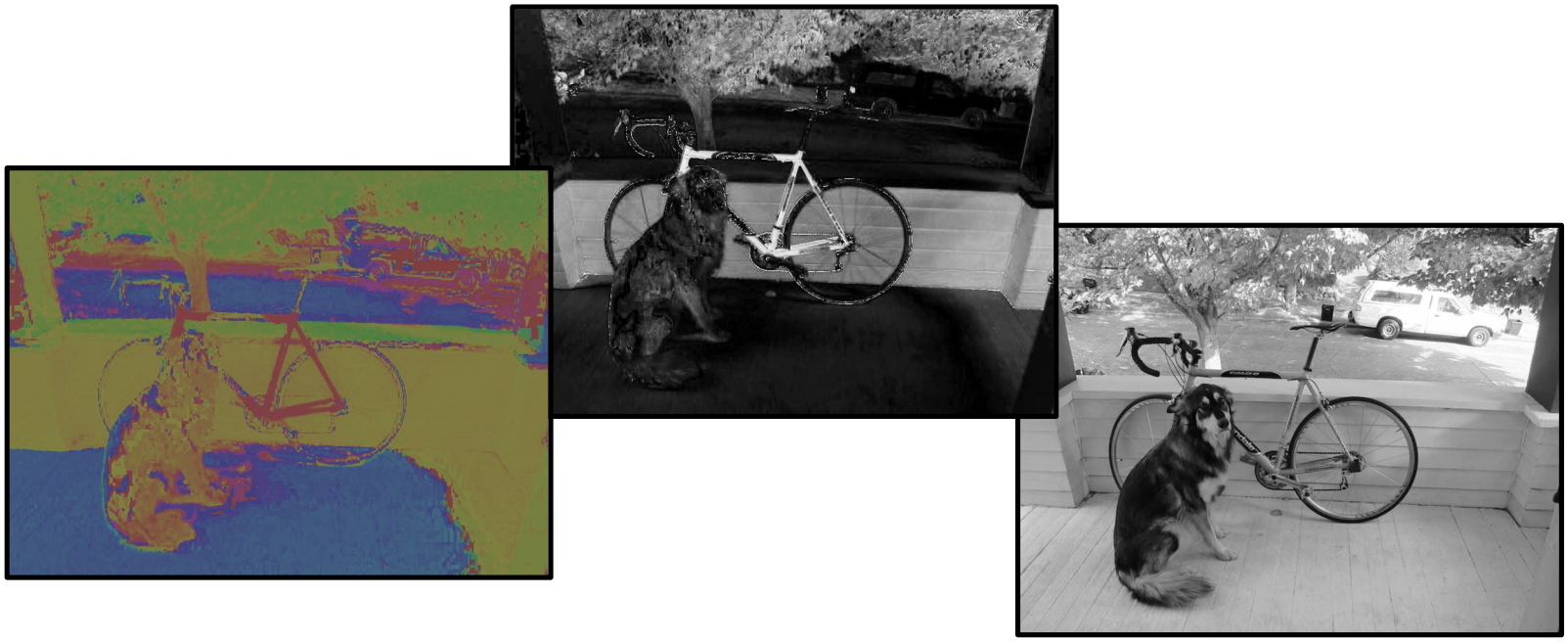
https://www.rapidtables.com/convert/color/hsv-to-rgb.html

Still 3D tensor, different info

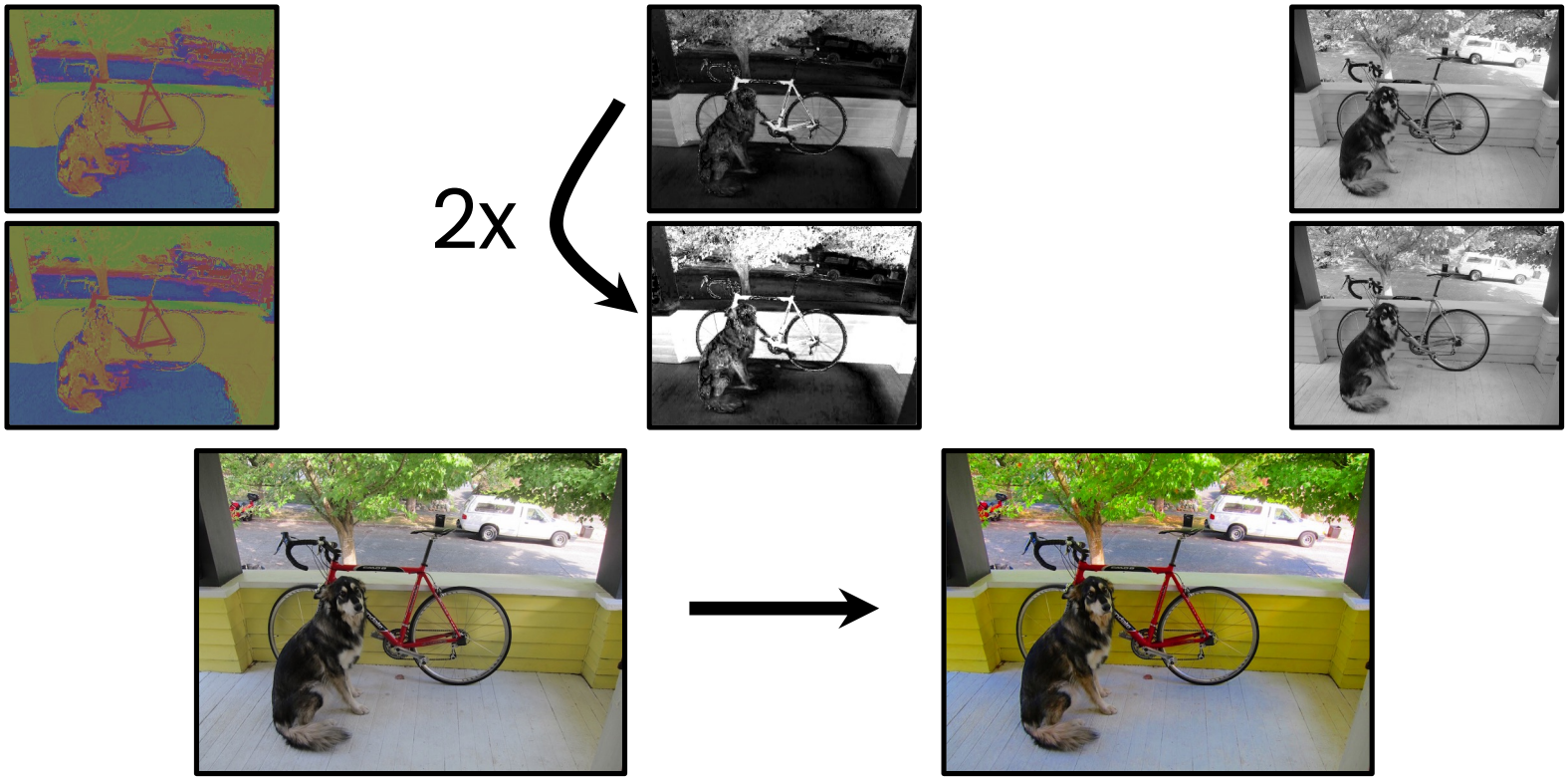




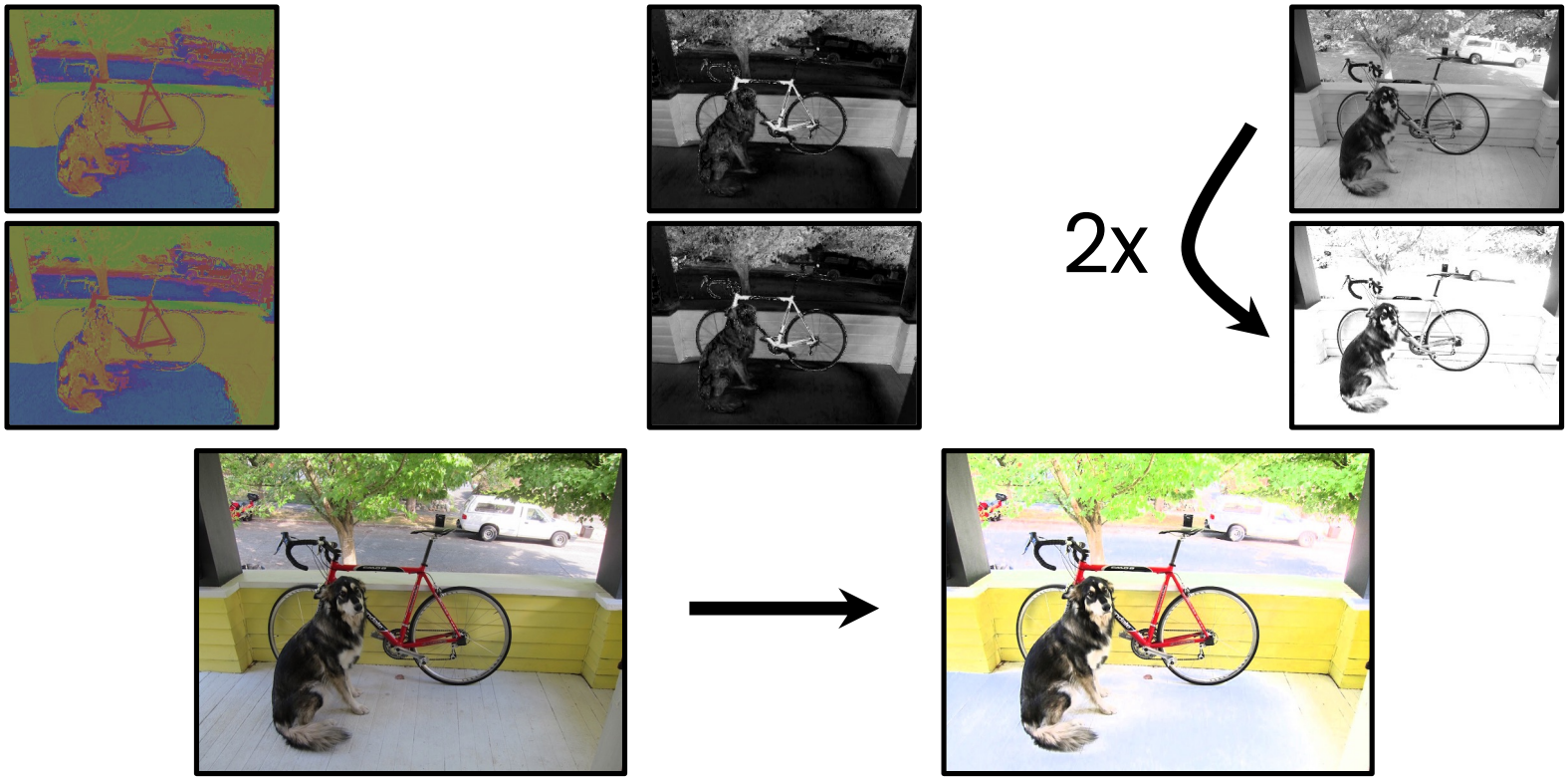
Hue Saturation Value



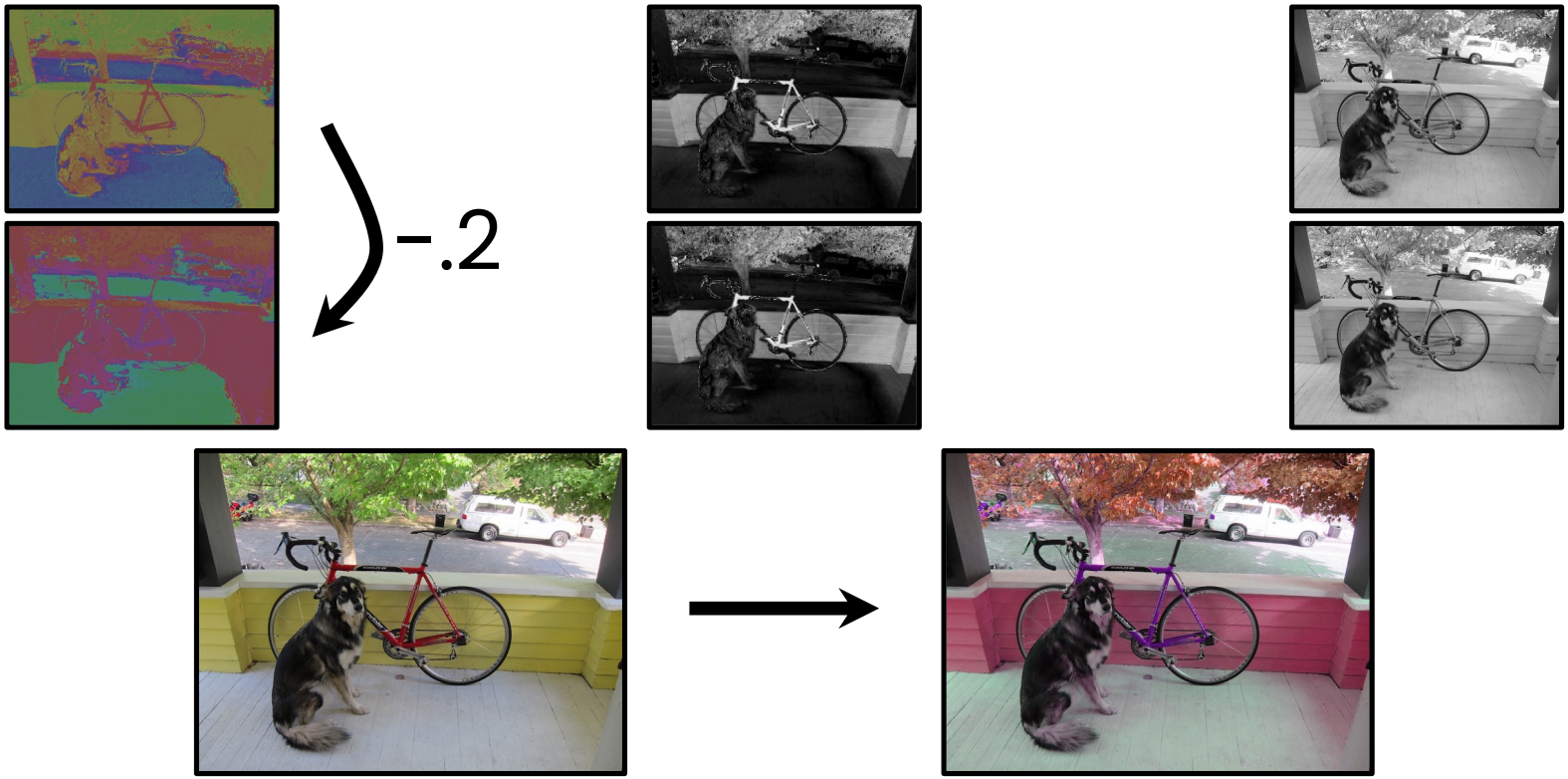
More saturation = intense colors



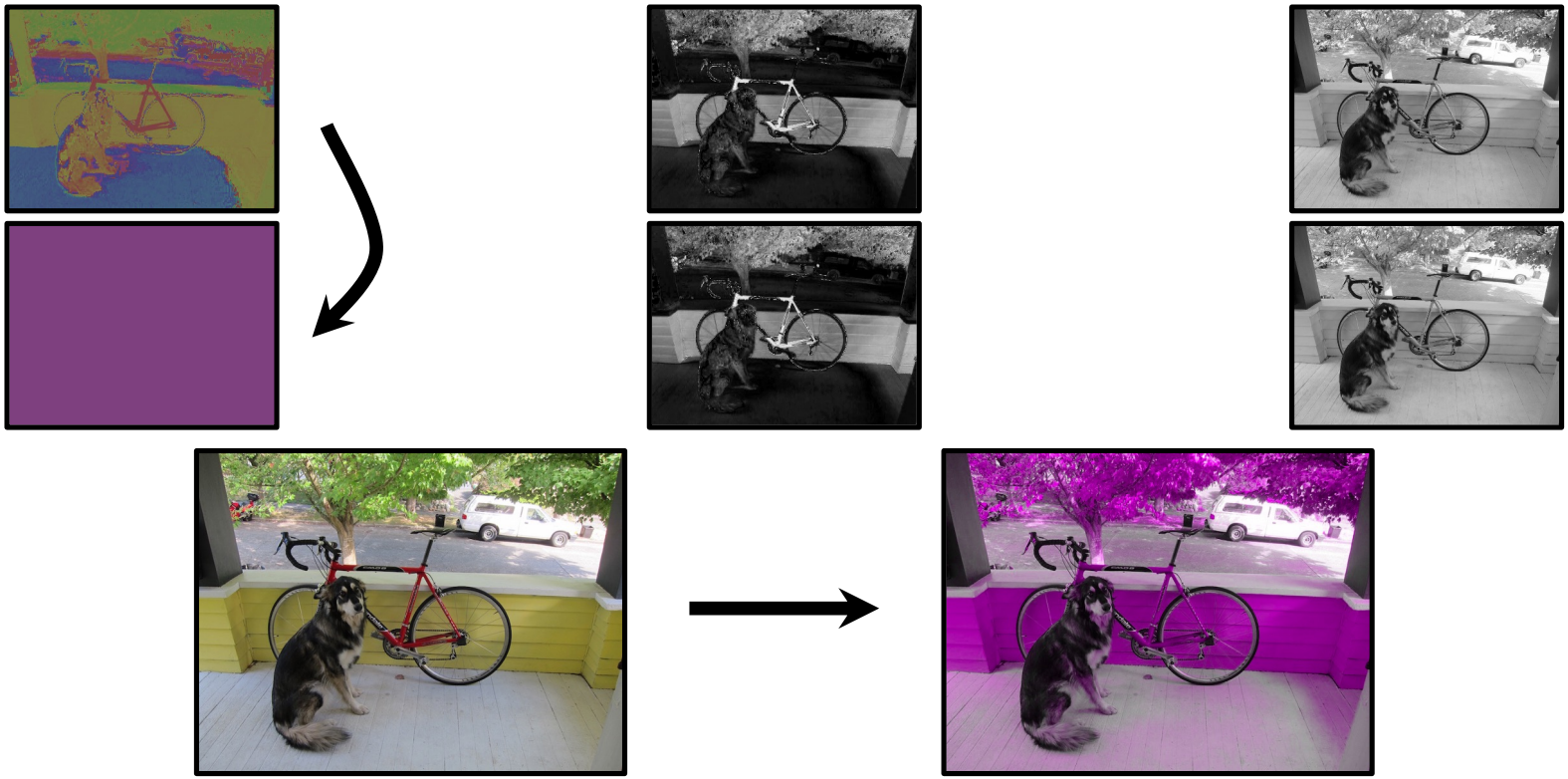
More value = lighter image



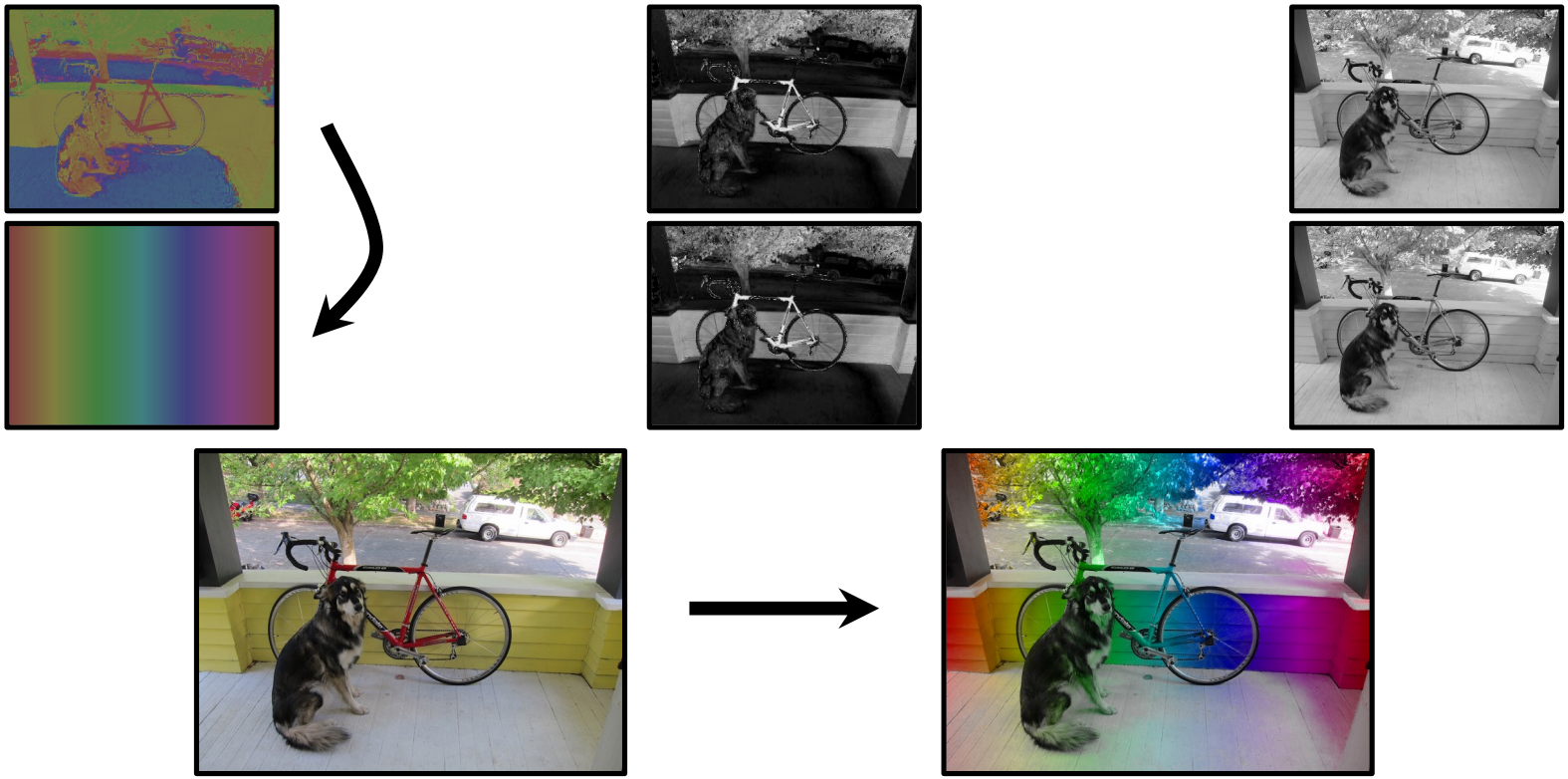
Shift hue = shift colors



Set hue to your favorite color!



Or pattern...



Increase and threshold saturation