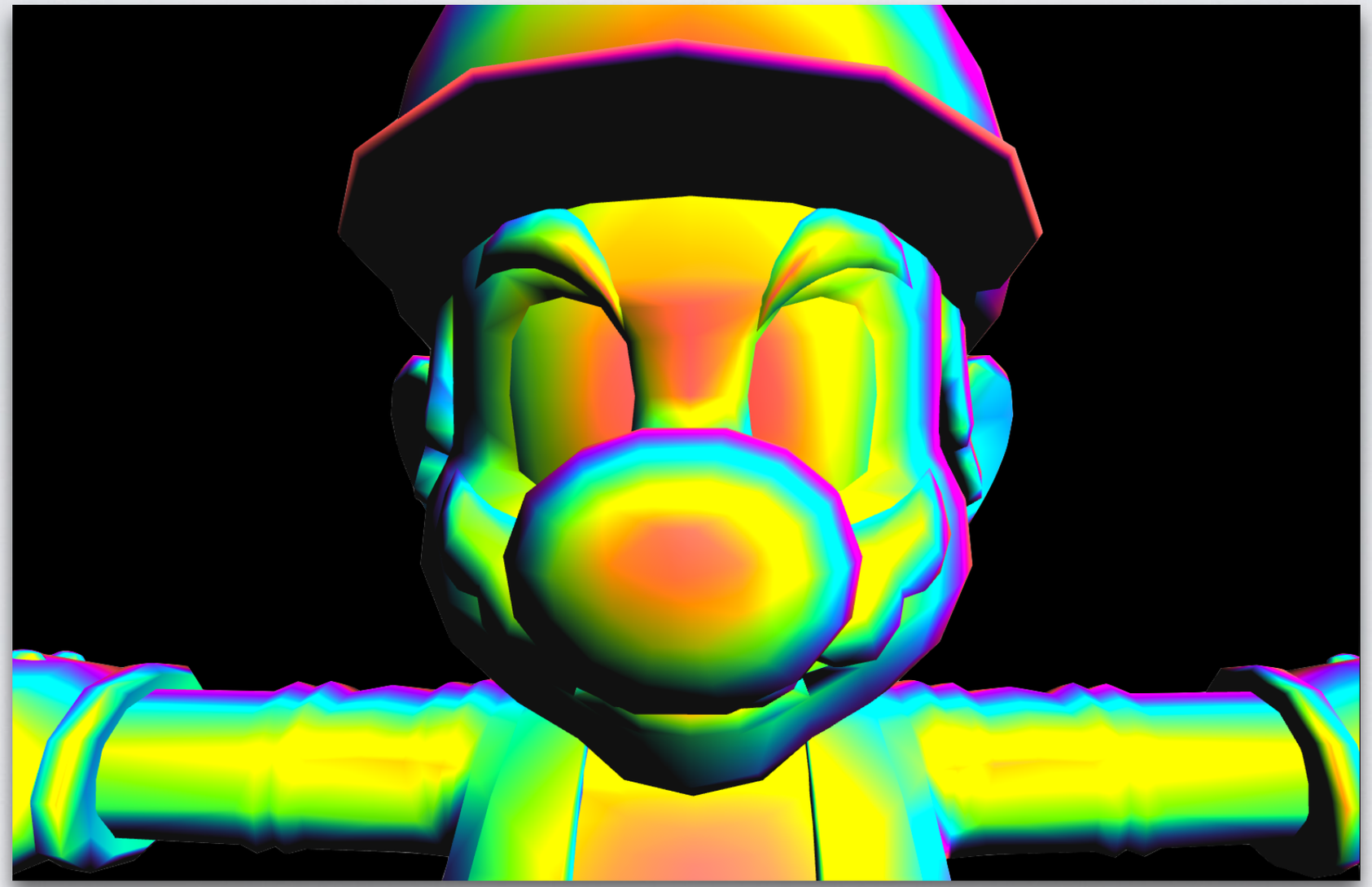
COLOR

Tips and tricks for the artistic mapping of color values



University of Pennsylvania - CIS 700 Procedural Graphics
Rachel Hwang

MAPPING PROBLEMS

Chocofur (source)

- Graphics is full of mapping problems. For example:
    - Geometry vertices to transformed positions
    - Then transformations through time as animation data
    - UV coordinates to texture coordinates
- Often we have some dataset, manually or procedurally specified
    - Then we use some mapping function to determine extra attributes, like normals or color
    - "Procedural graphics" is misleading — much of graphics is "procedural"! Proceduralism is fuzzy.

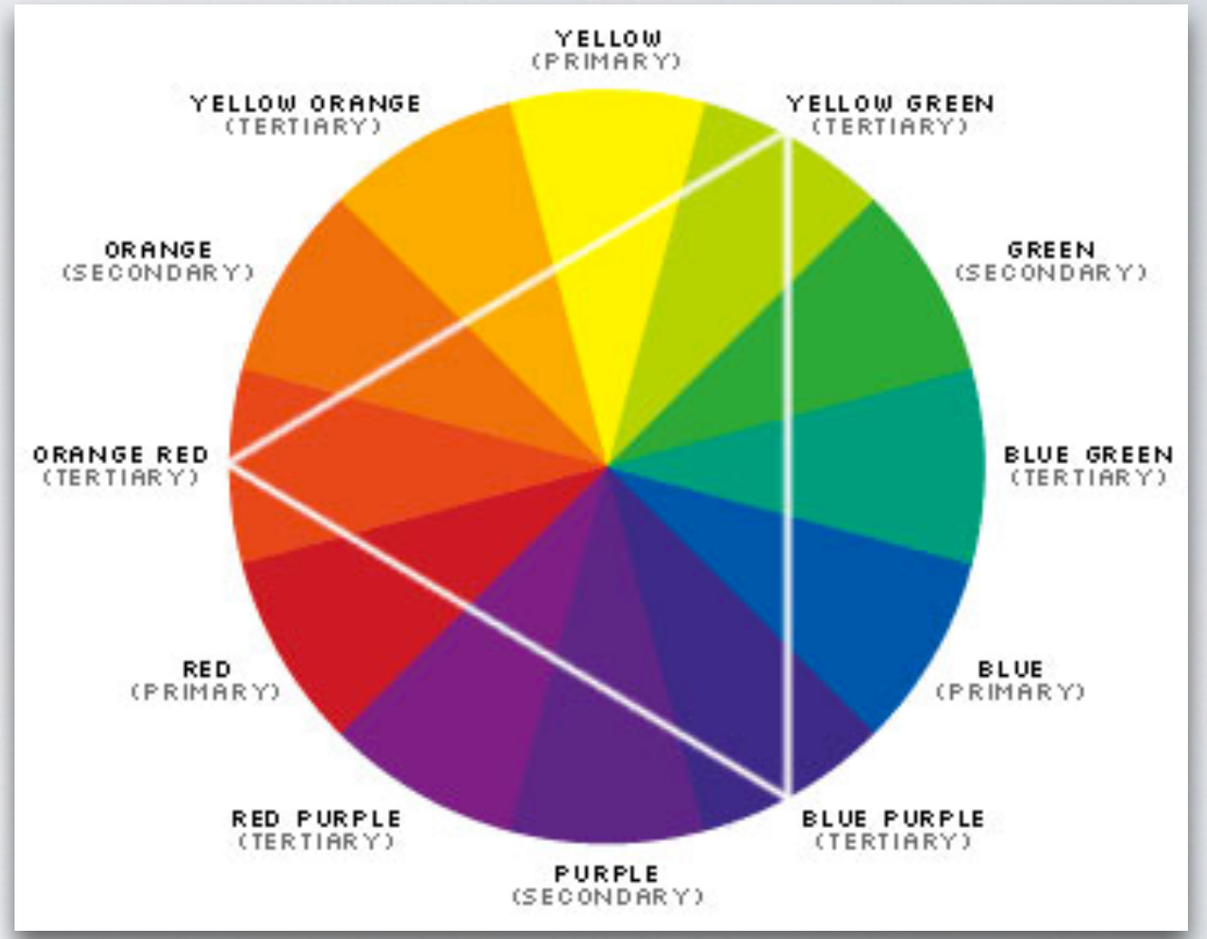
COLOR IS POWERFUL

Leonid Afremov (source)

- Influences human perception tremendously
- In CG, we're just creating a sequence of pixel colors to put on-screen based on some data.

SUPER BRIEF COLOR THEORY

- Colors: primary, secondary, tertiary composition
- Pretty color palettes usually consist of colors with some logical relationship. Eg.
    - Complementary - opposing colors
    - Analogous - adjacent colors
    - Color Triad - three equidistant colors
    - Generally, limit range of hue, luminance, etc.
    - Adobe color-palette picker
- To us procedural artists, we can treat color as just another dataset
    - 3D values (r, g, b)
    - We can map colors to or from any space we like procedurally!



nyu (source)

~DISCLAIMER~

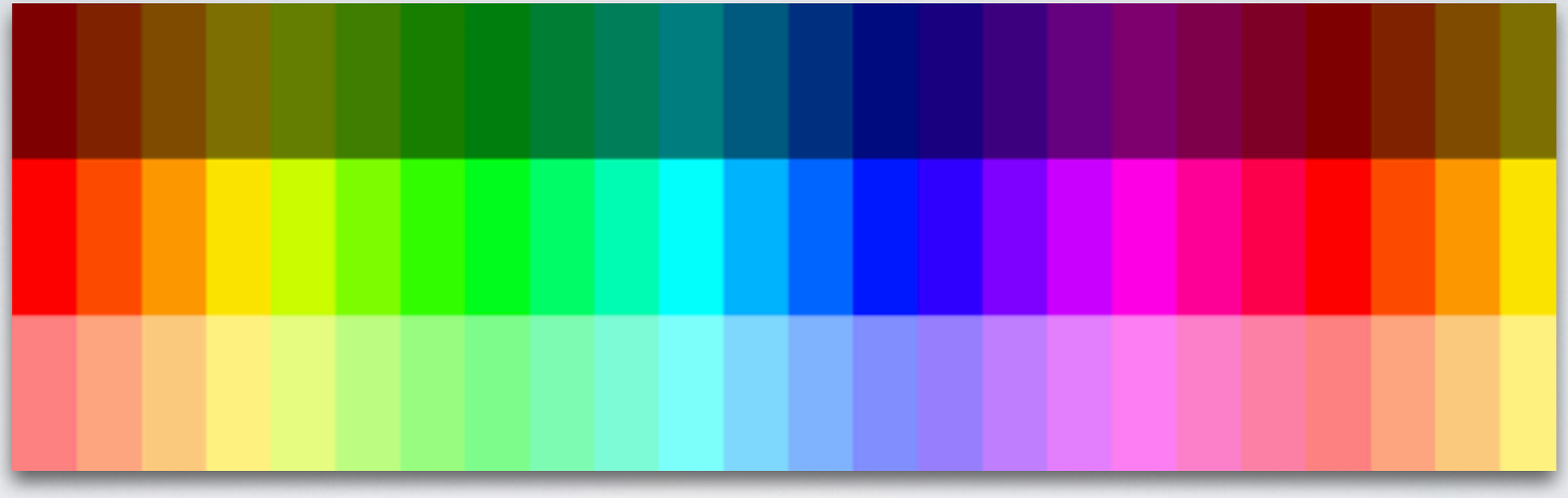
The following is a motley assortment of shading and image-processing effects, not a canonical selection, and not the most efficient algorithms.

Take these as inspiration in developing an intuition for programming visual effects.

COLOR PALETTE

TECHNIQUES

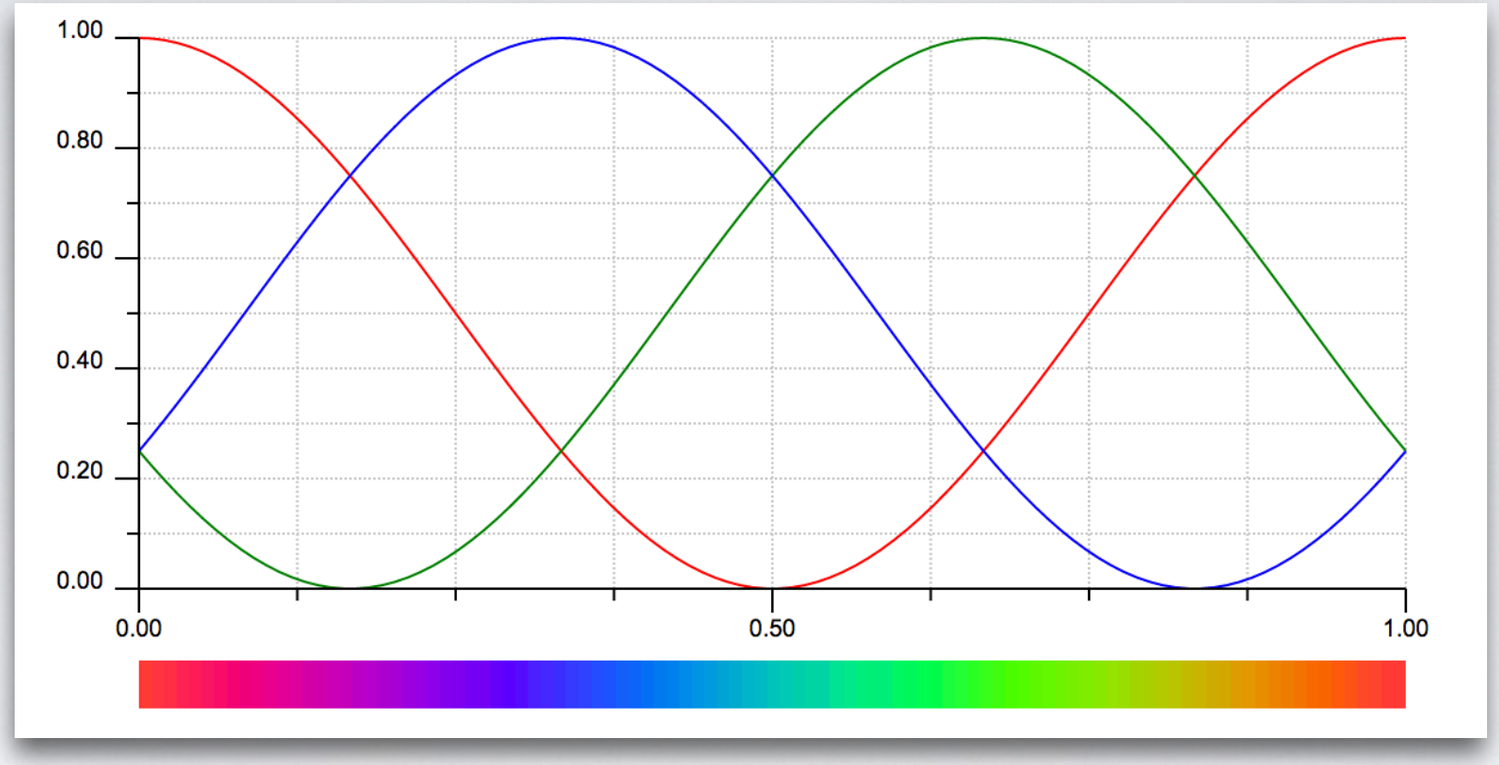
CONSIDERATIONS



Devmag (source)

- Vector distance in color space (rgb, hsv, etc) usually doesn't match difference in perception.
- Digital color representation is imperfect and cannot capture all natural colors.
- Convenient to generate 1D or 2D color palettes to create color variation as we vary some parameter(s). (Like with noise values!)
    - Vary color across an object that would have a constant color
    - Apply color to things that have no color defined for them, (eg. originally greyscale)

COSINE COLOR PALETTES



dev.thi.ng (source)

- Observation: Varying rob component(s) smoothly will result in a smooth change in color.
- IQs idea: modulate color value using cosine functions!

QUICK COSINE REVIEW

$$\text{color(t)} = \text{a} + \text{b} * \cos(2\,\pi(c * t + d))$$

- These are the four knobs with which we can control our cosine function
  - **a** : shifts the entire curve up or down along the y-axis
  - **b** : scales the amplitude. Increase makes the wave taller, decrease for shorter
  - **c** : scales the frequency. Increase makes the cycle faster, decrease for slower
  - **d** : shifts the entire curve left or right along the y-axis
- Try for yourself here.

COSINE COLOR PALETTES

a	b	c	d	palette
0.5, 0.5, 0.5	0.5, 0.5, 0.5	1.0, 1.0, 1.0	0.00, 0.33, 0.67	
0.5, 0.5, 0.5	0.5, 0.5, 0.5	1.0, 1.0, 1.0	0.00, 0.10, 0.20	
0.5, 0.5, 0.5	0.5, 0.5, 0.5	1.0, 1.0, 1.0	0.30, 0.20, 0.20	
0.5, 0.5, 0.5	0.5, 0.5, 0.5	1.0, 1.0, 0.5	0.80, 0.90, 0.30	

- For vec3 output, we use vec3 input parameters. Try it here.
- Using parameterized cosine waves for each channel, we can smoothly move between various colors.
  - **A** = [0.50 , 0.50 , 0.50]
  - **B** = [0.50 , 0.50 , 0.50]
  - **C** = [1.00 , 1.00 , 1.00]
  - **D** = [0.00 , 0.33. , 0.67]

Parameters for red curve

Parameters for blue curve

Parameters for green curve

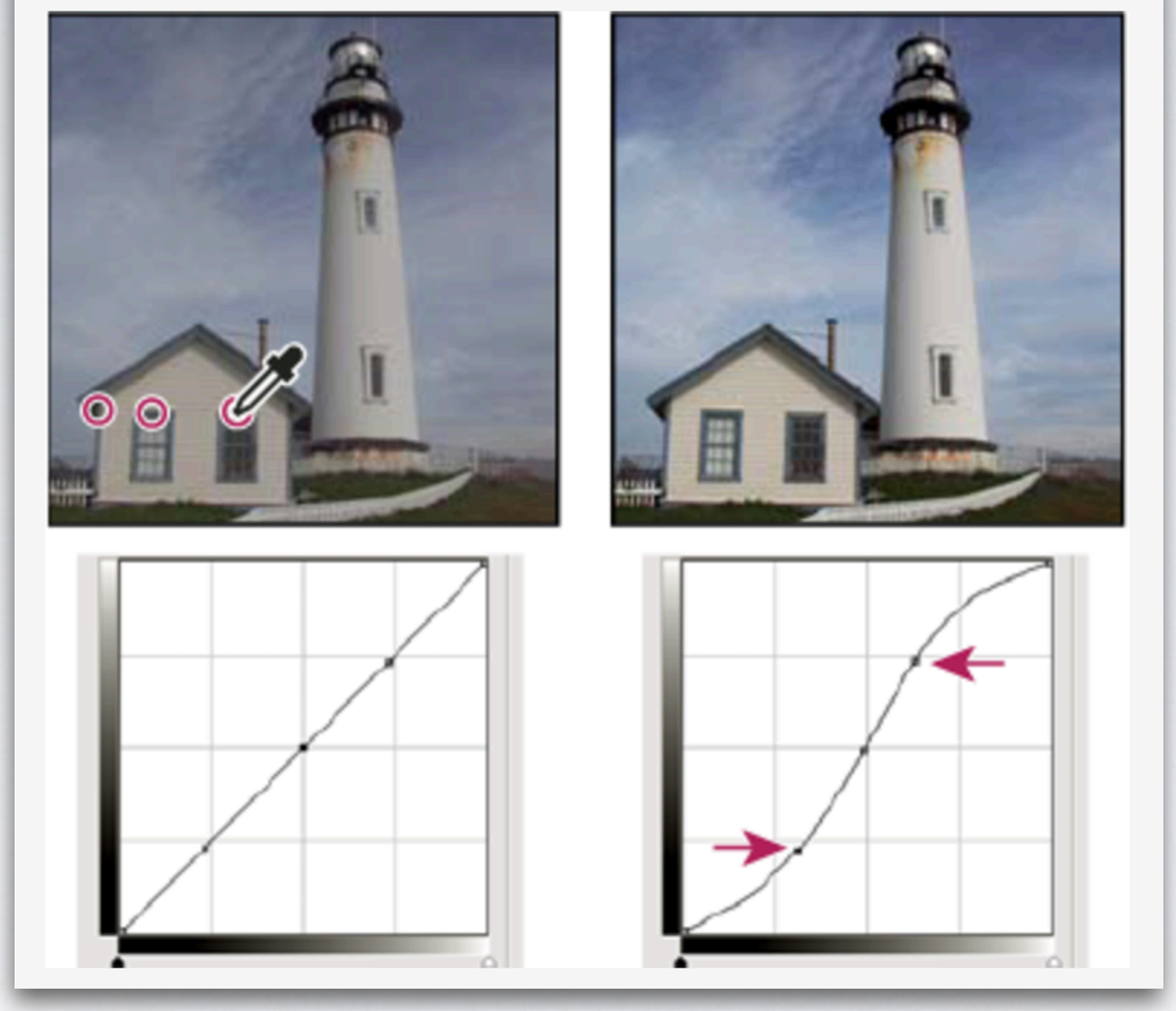
INSTAGRAM-Y FILTERS

Photodoto (source)

Original **“Brannan” filter**

- Effects like Instagram filters are just more color-remapping effects!
- Brannan filter: increase contrast + brightness, blend with yellow color, remap full value range to exclude darkest values.

INSTAGRAM-Y FILTERS



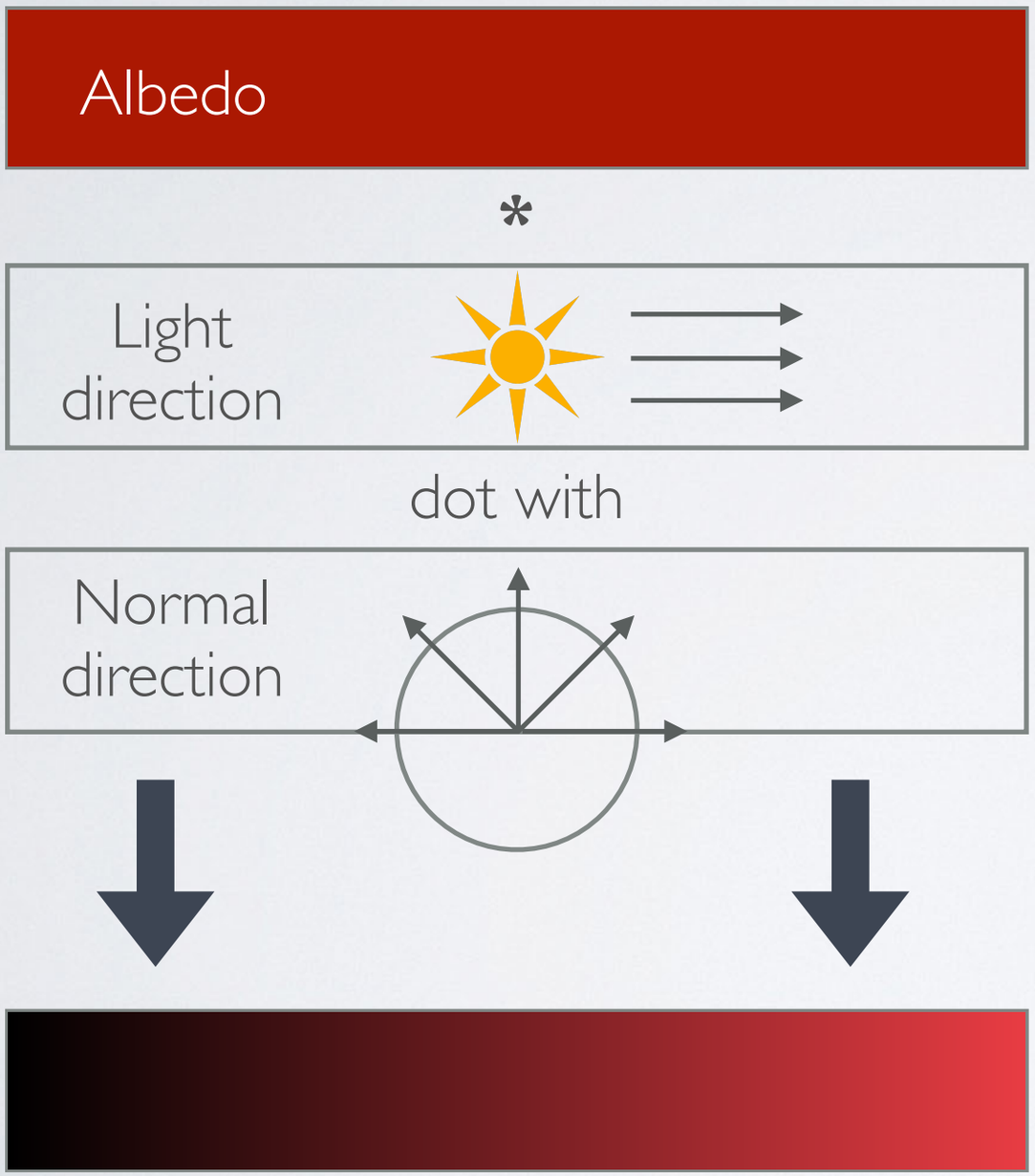
Photodoto (source)

- Software like Photoshop provide handy visualization tools for color remapping
- Above: increasing contrast. Pinch the curve so the middle tones are less represented

SHADING IDEAS

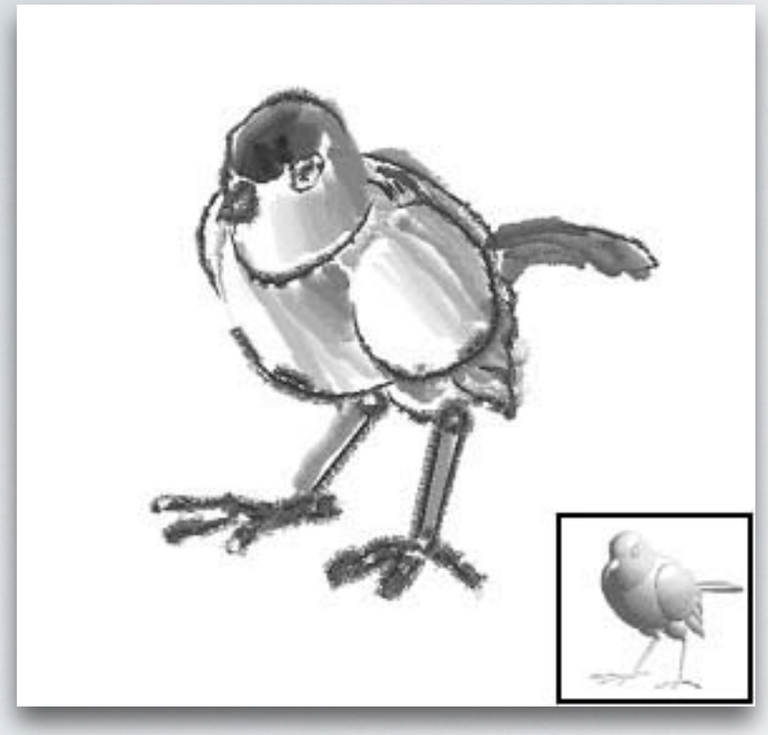
THE RENDERING STATUS QUO

Lambert shading



- Rendering is already full of procedural shading!
- We just usually try to mimic the physical properties of light for realism eg. light diffusion
- Lambert shading is just a procedural formula: scale base color by dot(normal, vecToLight)
- But, why stick to physically-based shading models?

NON-PHOTOREALISTIC RENDERING (NPR)



Ming OuhYoung (source)

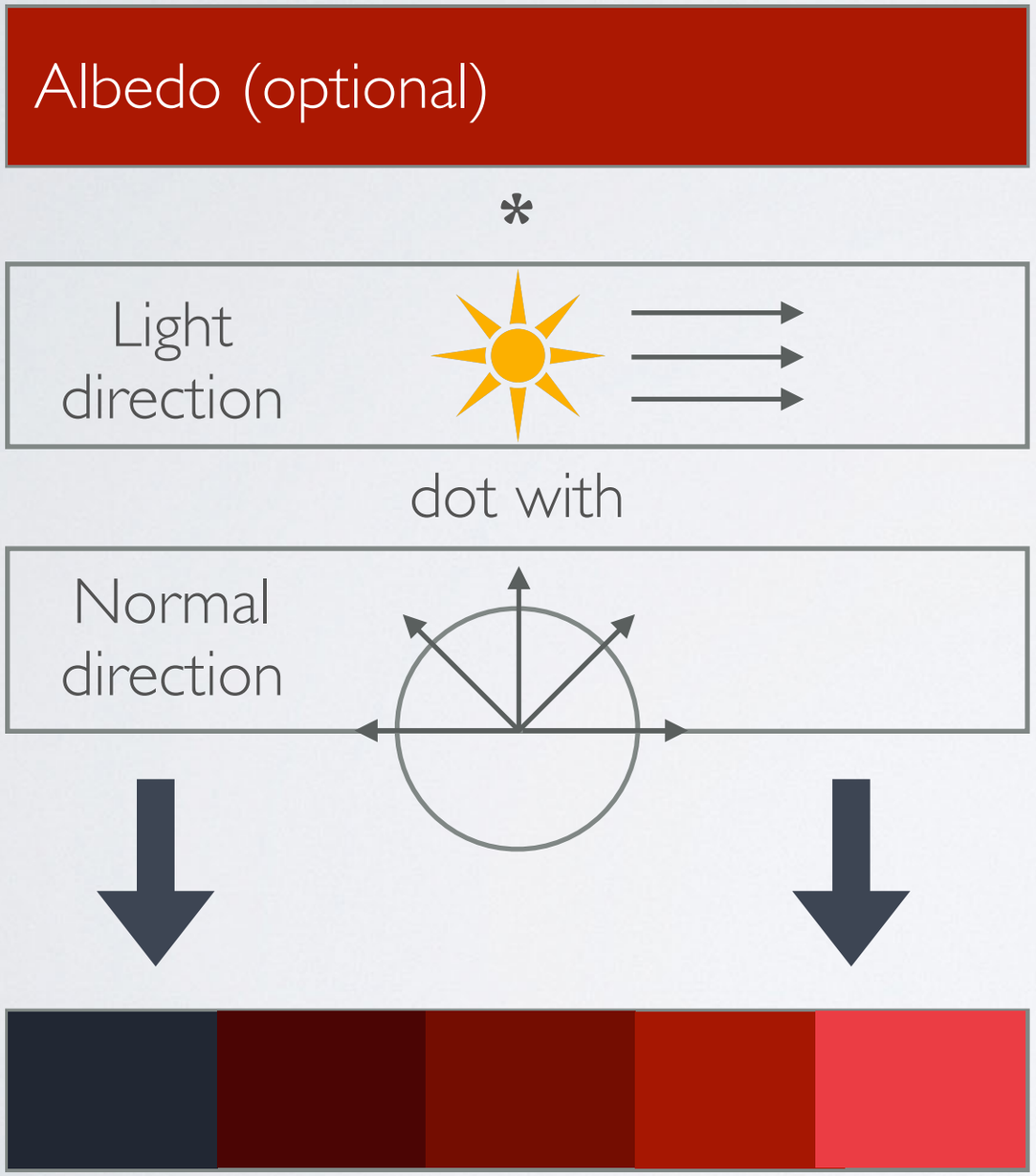
Franz Peschel (source)

Cmu (source)

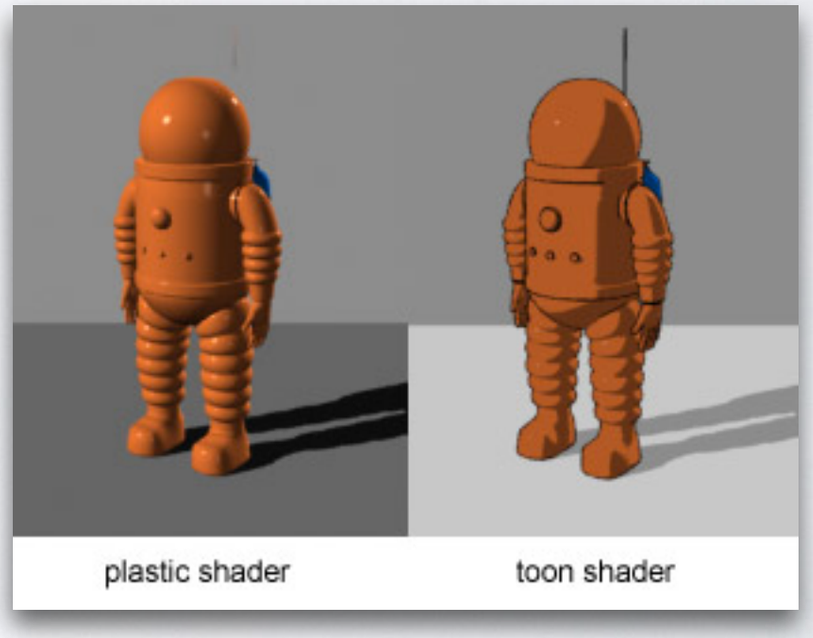
- With some creative programming, we can mimic many artistic styles
- Much stylization is defined by shading and coloring…how does a material respond to light?
- Hatch-shader demo, various NPR effects demo

TOON SHADING

cell shading



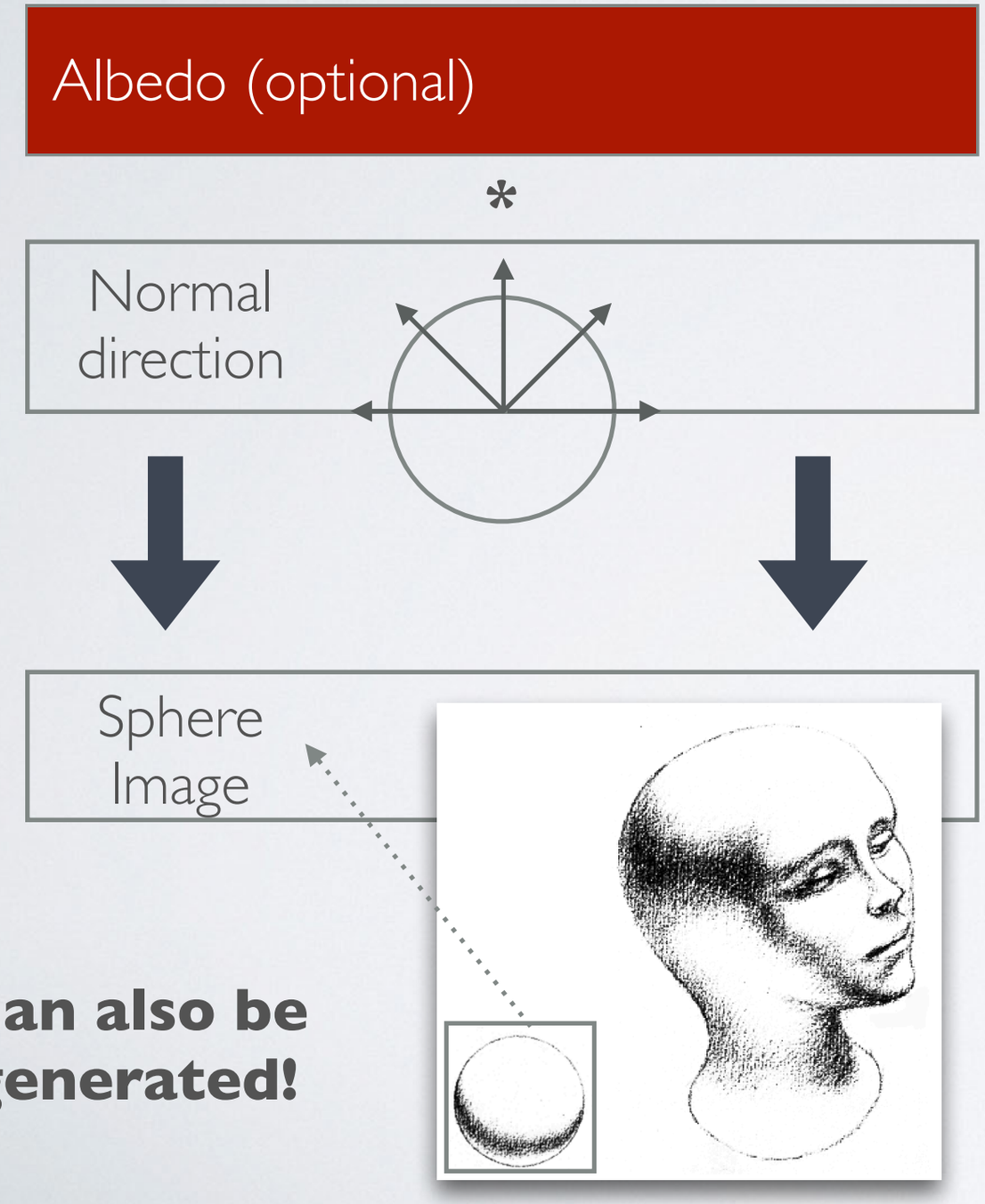
- Mimics cell-shading, an artistic simplification
- Similar to lambert shading, but discretizes the output color space
- Output color: procedurally or manually specified
- Can add an outline by coloring black when surface normal is perpendicular to view vector
- Windwaker demo



T-Tus (source)

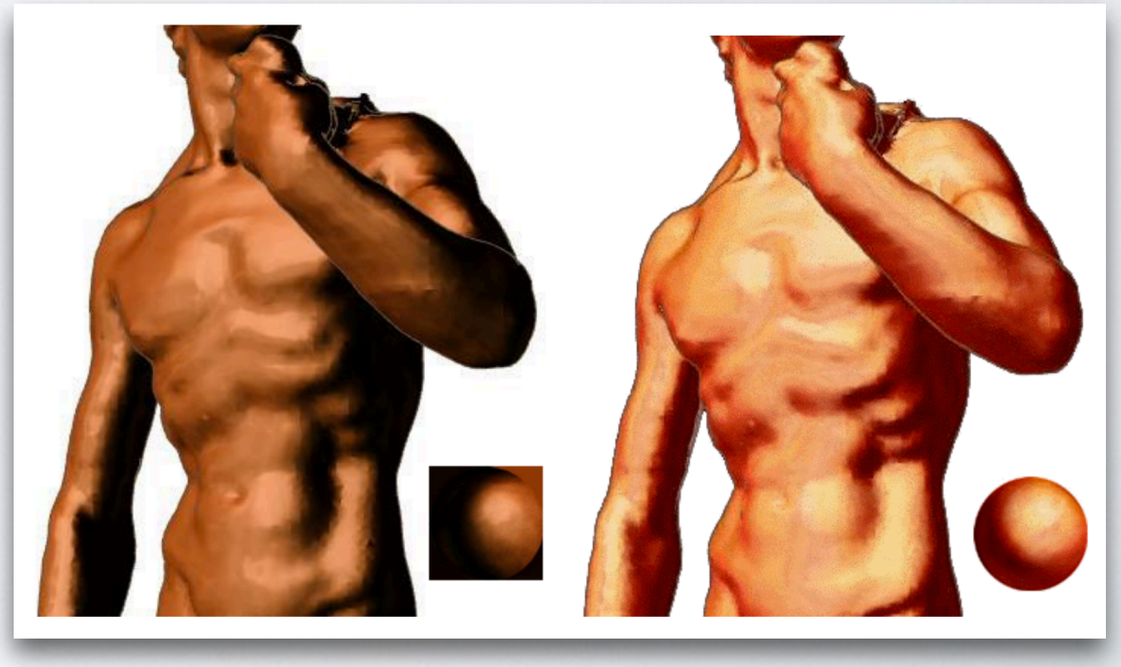
LIT SPHERE SHADING

lit sphere shading



Can also be generated!

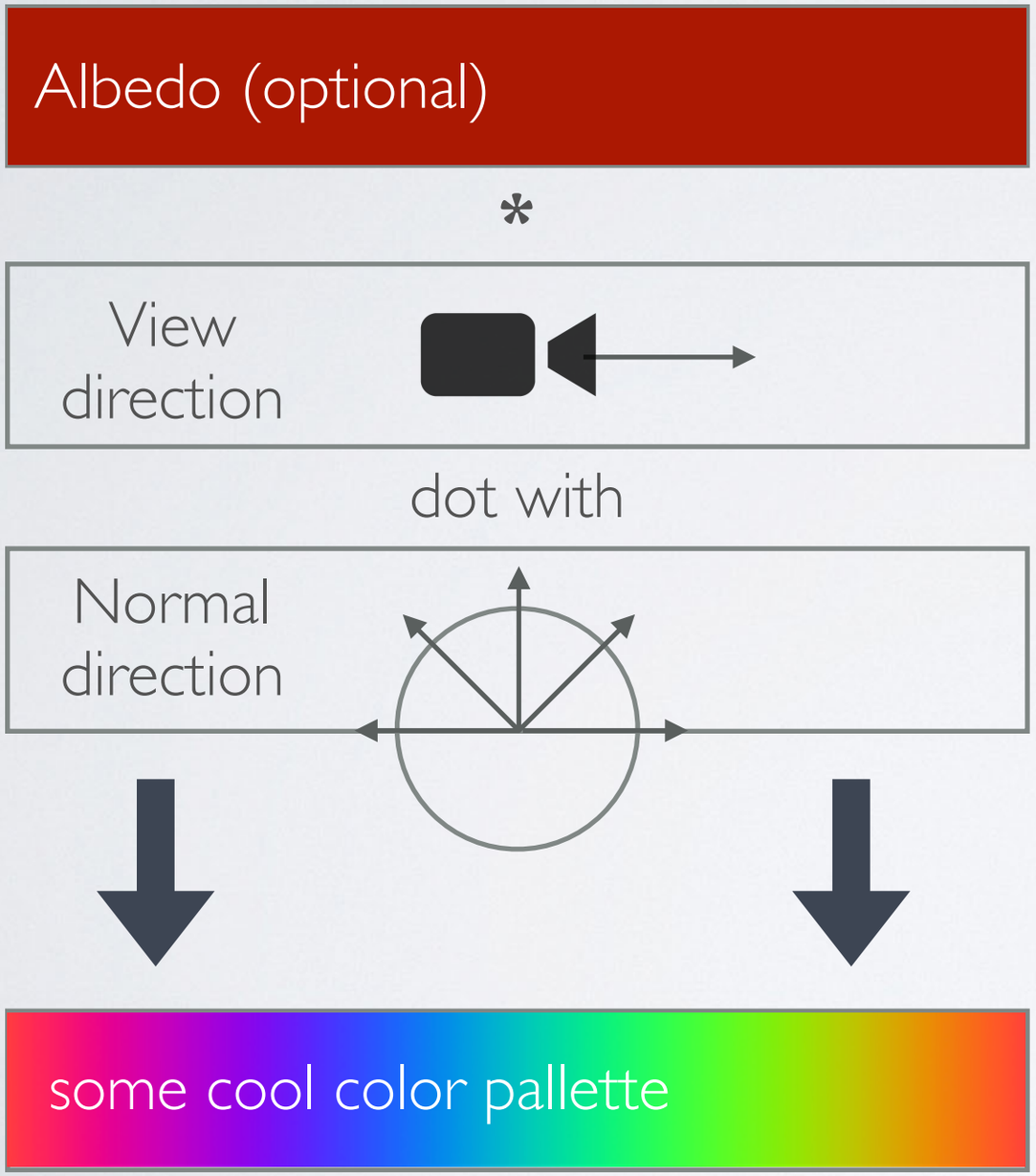
- A sphere covers the full set of unit normals.
- "Fake" reflectance models by reading color from a sphere-image texture rather than computing.
- Map normal directions to image texture of a sphere. (Like normal-mapping backwards!)
- Can encode a huge variety of styles! Allows you to draw your own reflectance model!
- Lit-sphere demo



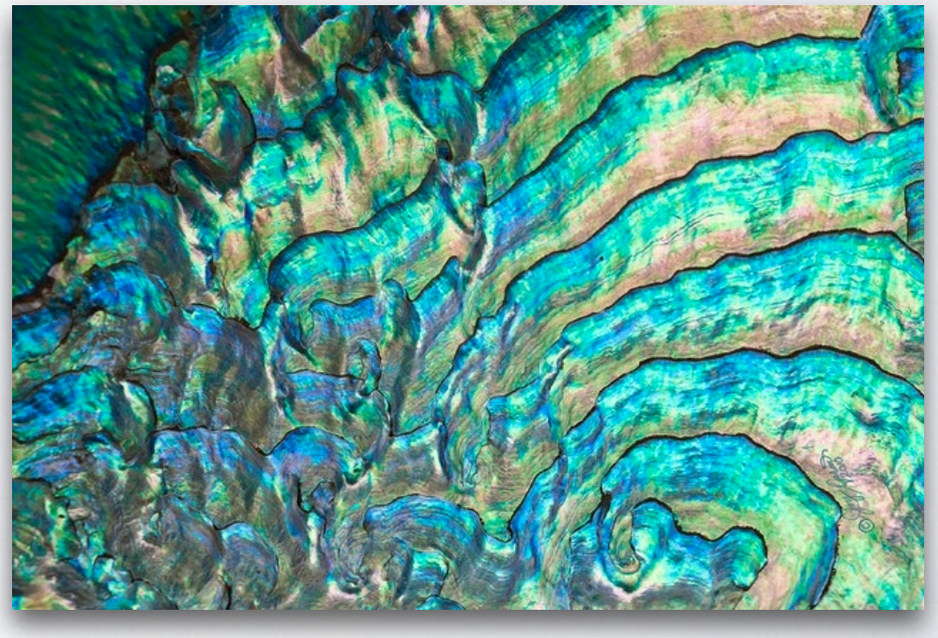
Lit Sphere (source)

IRIDESCENT SHADING

iridescent shading



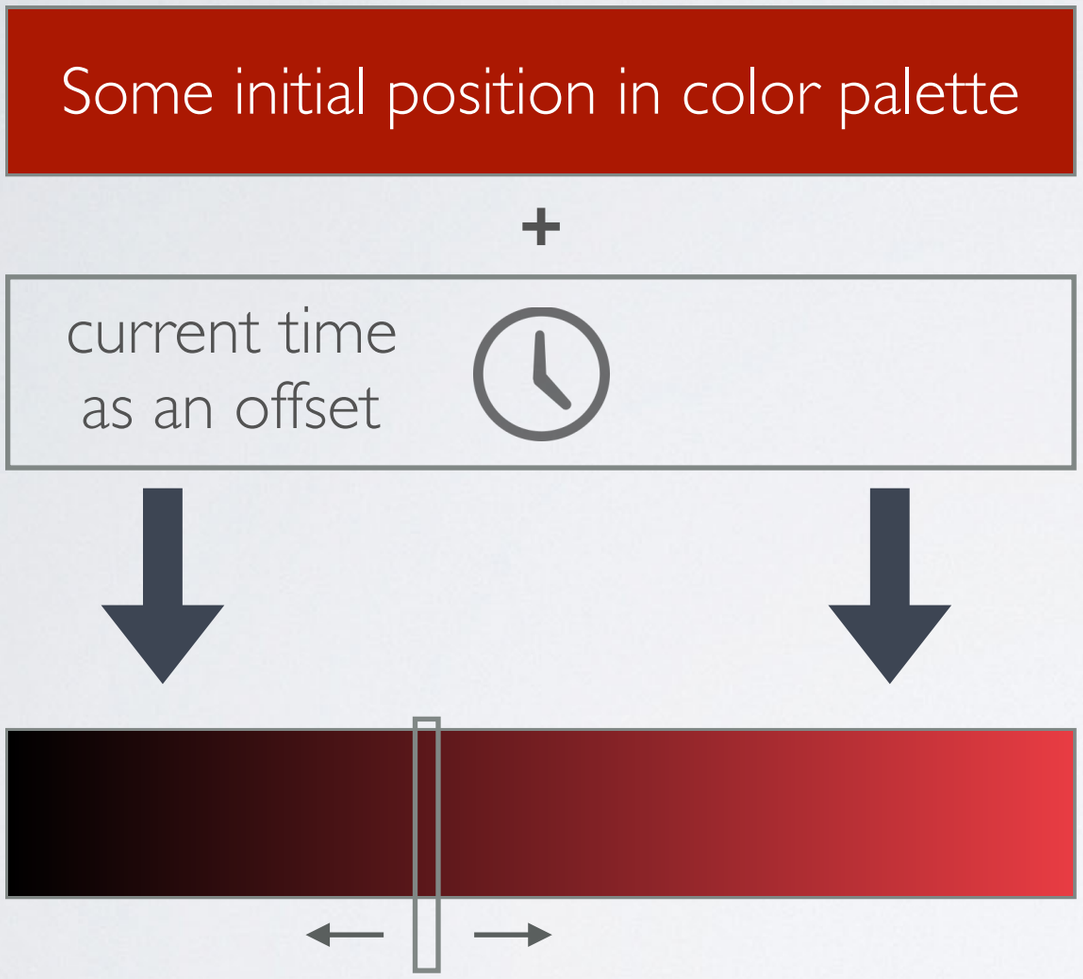
- Color is dependent on the viewing angle, appears to shimmer and change with rotation
- Implementation is similar to lambert, but with the view vector instead of the light vector.
- Looks like this. Ok, physically-based.



Indulgy (source)

ASSORTED POST-PROCESSING EFFECTS

COLOR CYCLING



Effectgames (source)

- Aka. "pallette shifting"
- See effect here. (look at options)
- Create cheap animation by offsetting over time into a texture or color map.

POINTILLISM

Pointillism shading

noise (position)

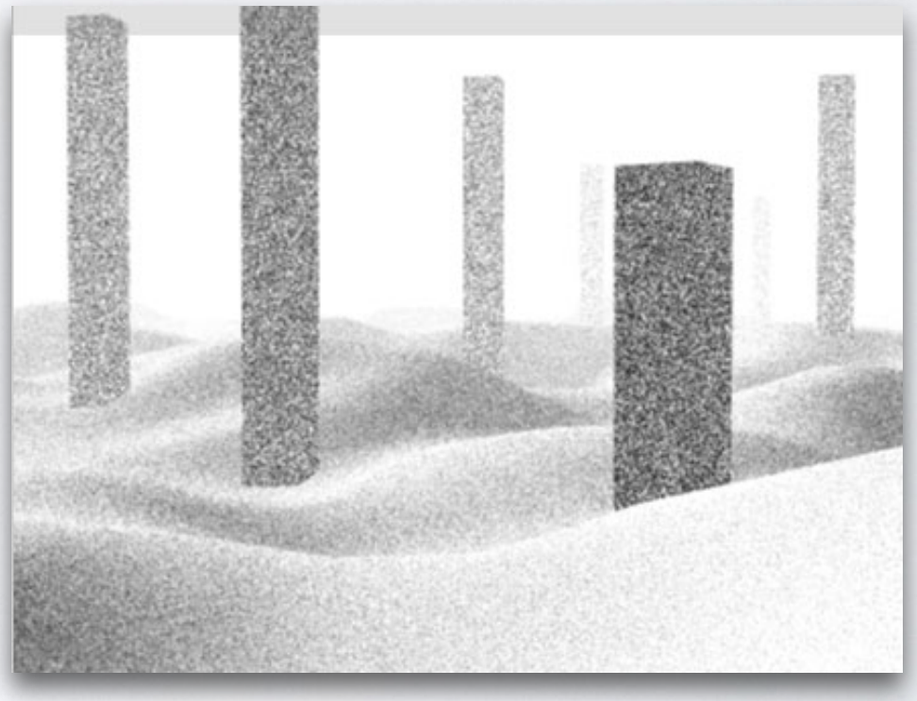
Compare to

Darkness (for use as a threshold val)

or Albedo color

Effect:

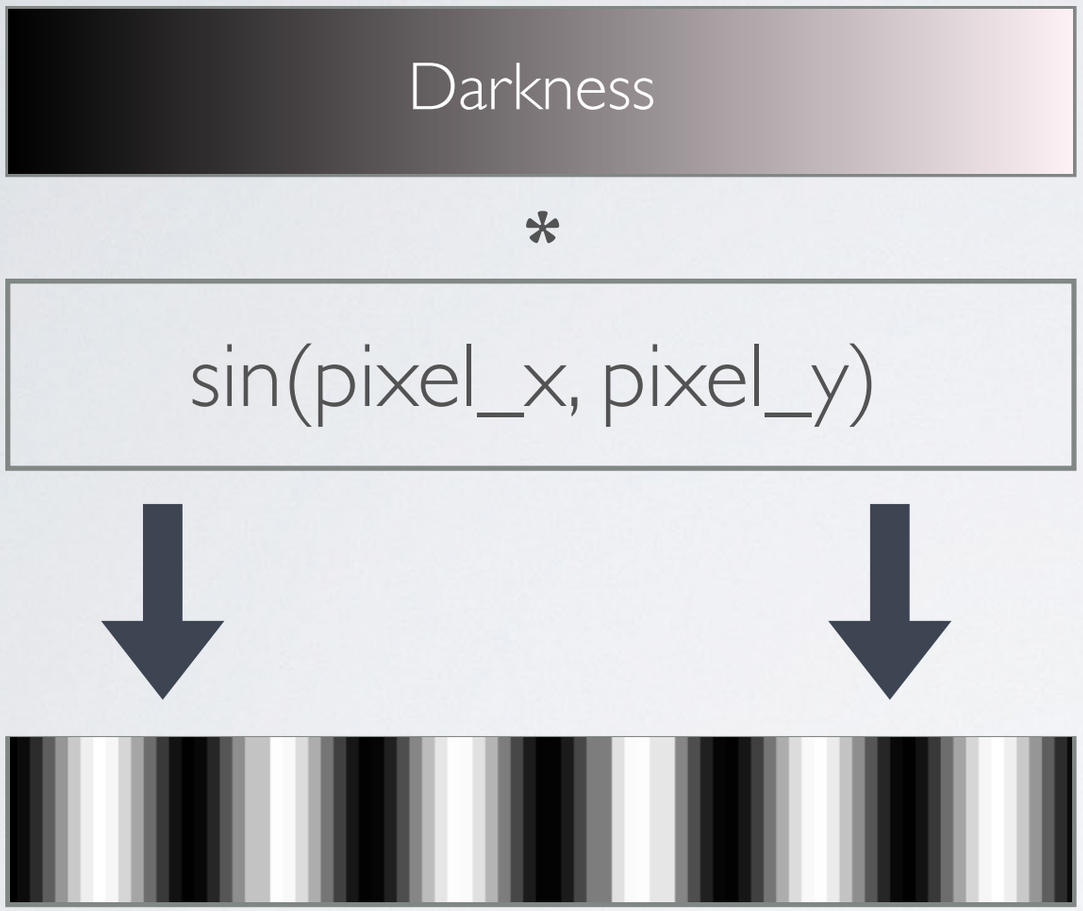
- The speckled effect — basically represents darkness using density of speckles
- We can approximate this density by applying color with some probability.
- Probability scales with original darkness value. Eg. if the original color was pure black, we color the pixel with 100% probability



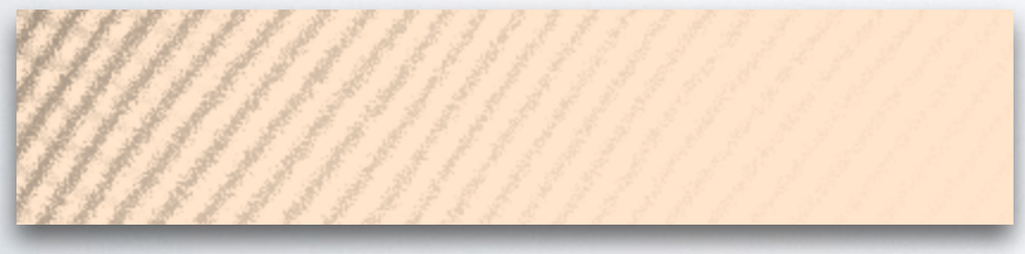
Eias3d (source)

HATCHING

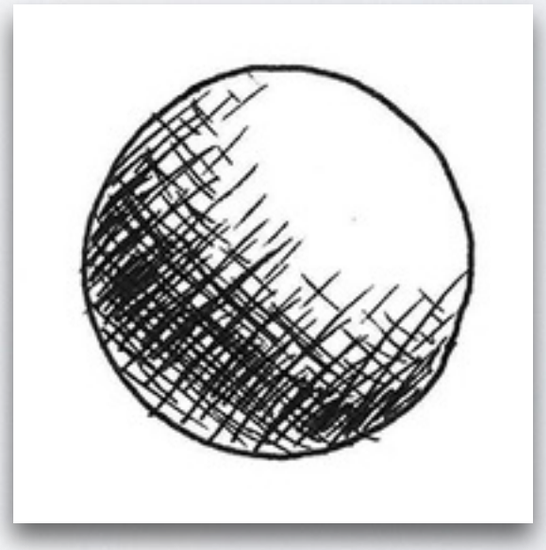
hatching shading



Effect:



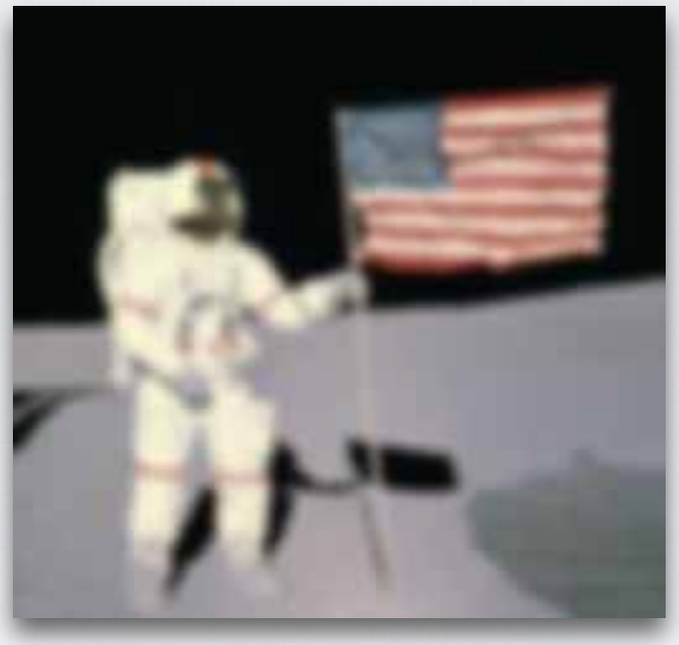
- Mimics the illustration technique of representing darkness with diagonal lines
- We can use a sine function to make periodic dark lines which look like hatches
- Use both x + y as an input to get a diagonal hatch
- Not perfect — would be better to also vary distance between hatches, but more complex
- See effect here



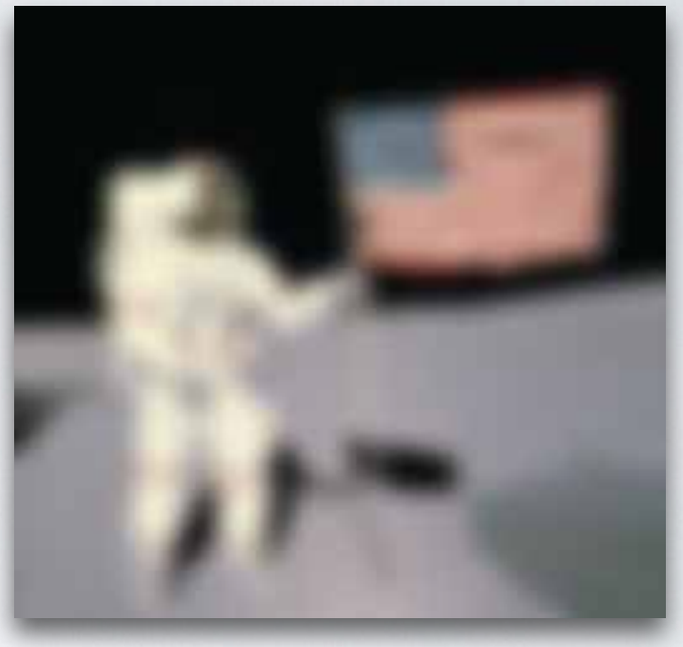
mstworkbooks (source)

GAUSSIAN BLUR

original



radius 2.5 px



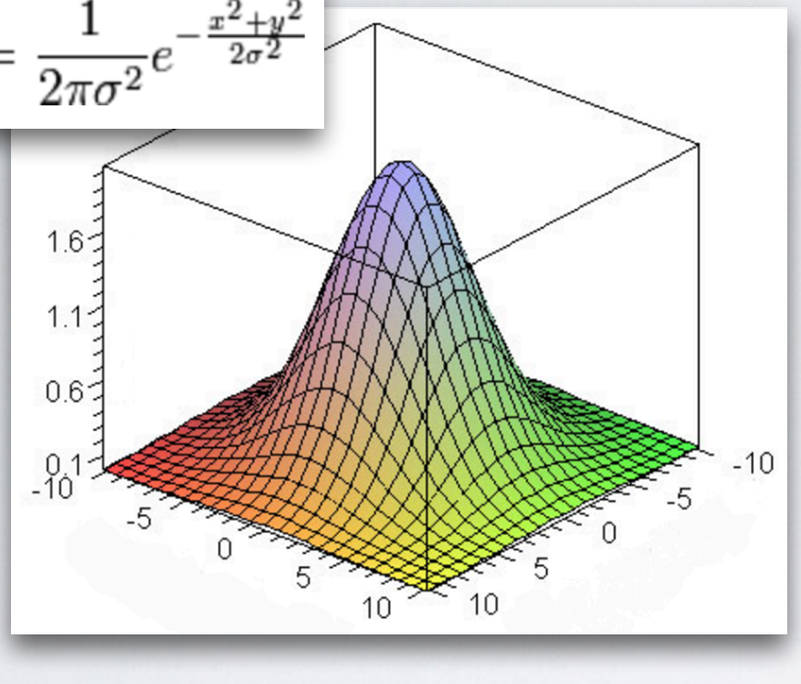
radius 5 px

websupergoo (source)

- We can achieve blur/smooth by averaging neighboring pixel values.
    - The more neighbors (larger radius within to consider), the more dramatic the blur effect
    - Closer pixels should contribute more, and further pixels less. We want to scale contribution by distance (like interpolation!)

GAUSSIAN BLUR

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



Rastergrid (source)

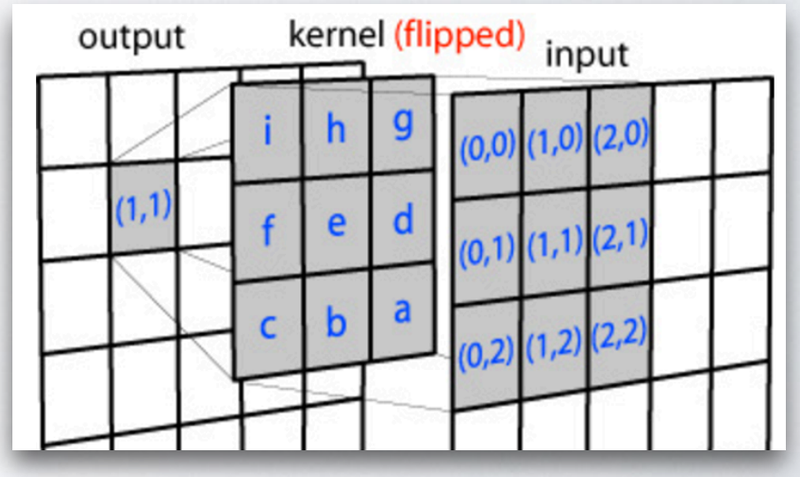
the (2D) kernel shape

$$\frac{1}{273}\begin{bmatrix} 1 & 4 & 7 & 4 & 1 \\ 4 & 16 & 26 & 16 & 4 \\ 7 & 26 & 41 & 26 & 7 \\ 4 & 16 & 26 & 16 & 4 \\ 1 & 4 & 7 & 4 & 1 \end{bmatrix}$$

bert (source)

possible pixel weights

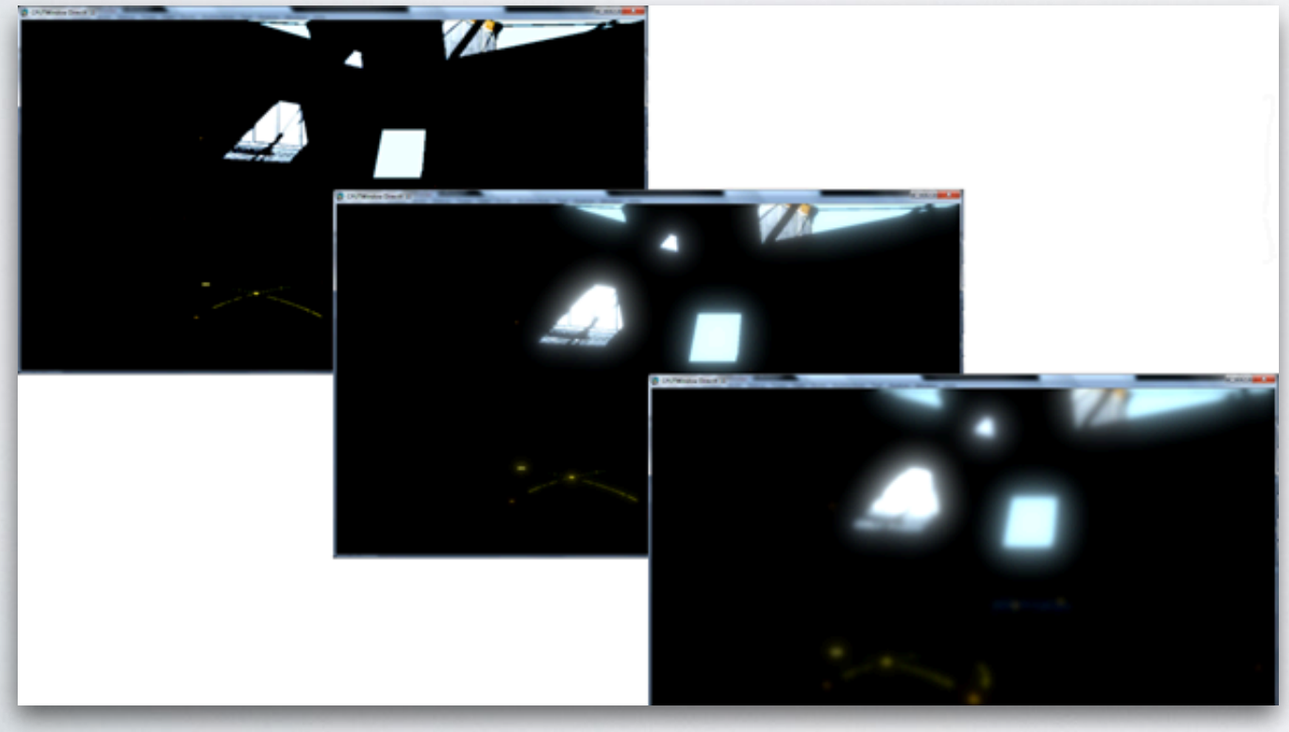
- Like much in signal processing, notation makes this look scary, but the concept is simple.
- This gaussian equation describes the weight that cells contribute based on their spatial relationship to the center.
- The Gaussian is a normal distribution — using it to weight neighboring pixel values in averaging does a smooth blend.



kernel application

BLOOM

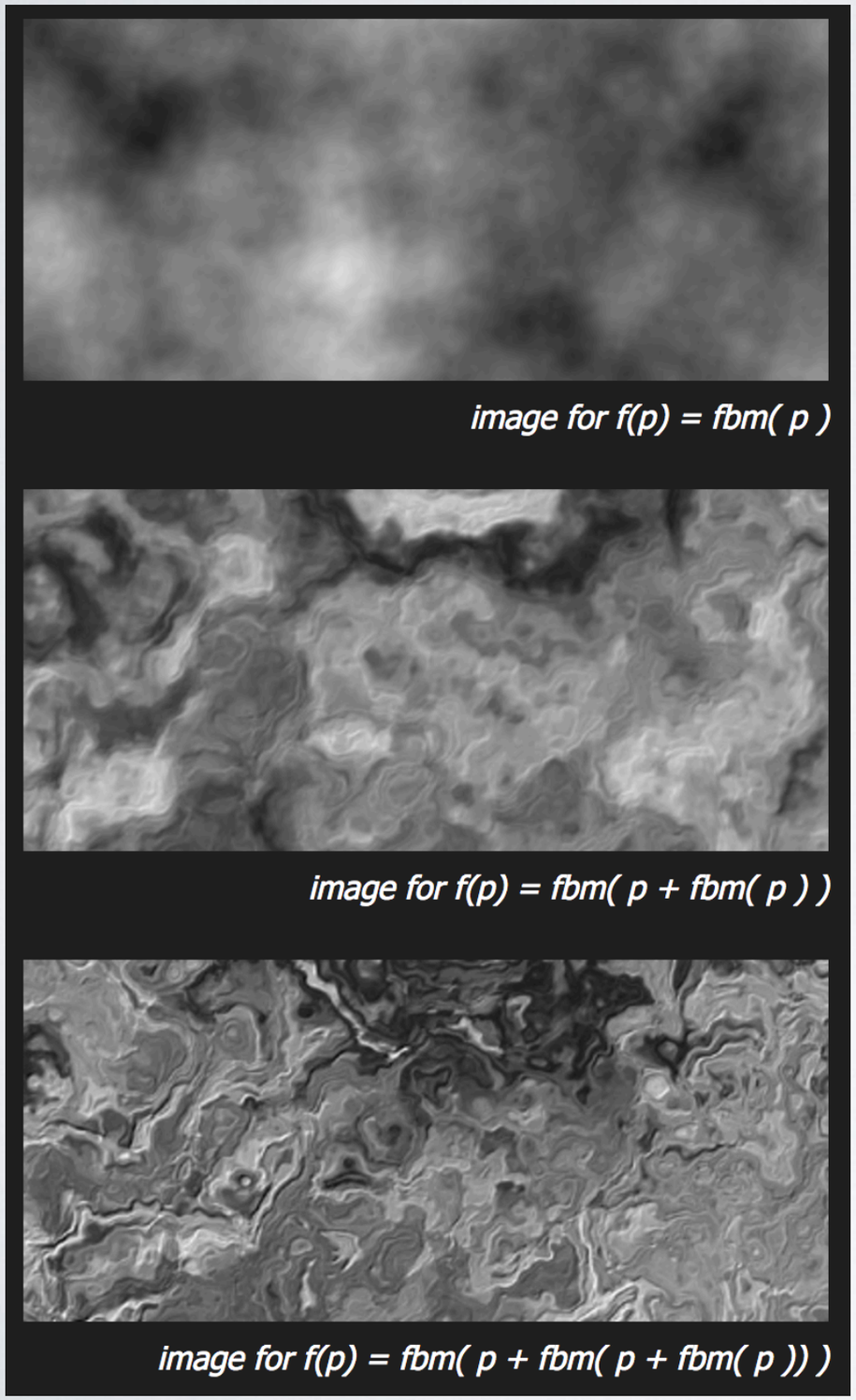
gamespot (source)



Intel (source)

- Creates a glow around bright parts of an image.
- First do a "high pass filter", extract pixels of high luminosity from your image. Store these bright pixels in a texture.
- Apply gaussian blur to the bright pixel image to create fake glow effect
- Blend the blurred bright image with the original image.

WARP EFFECTS

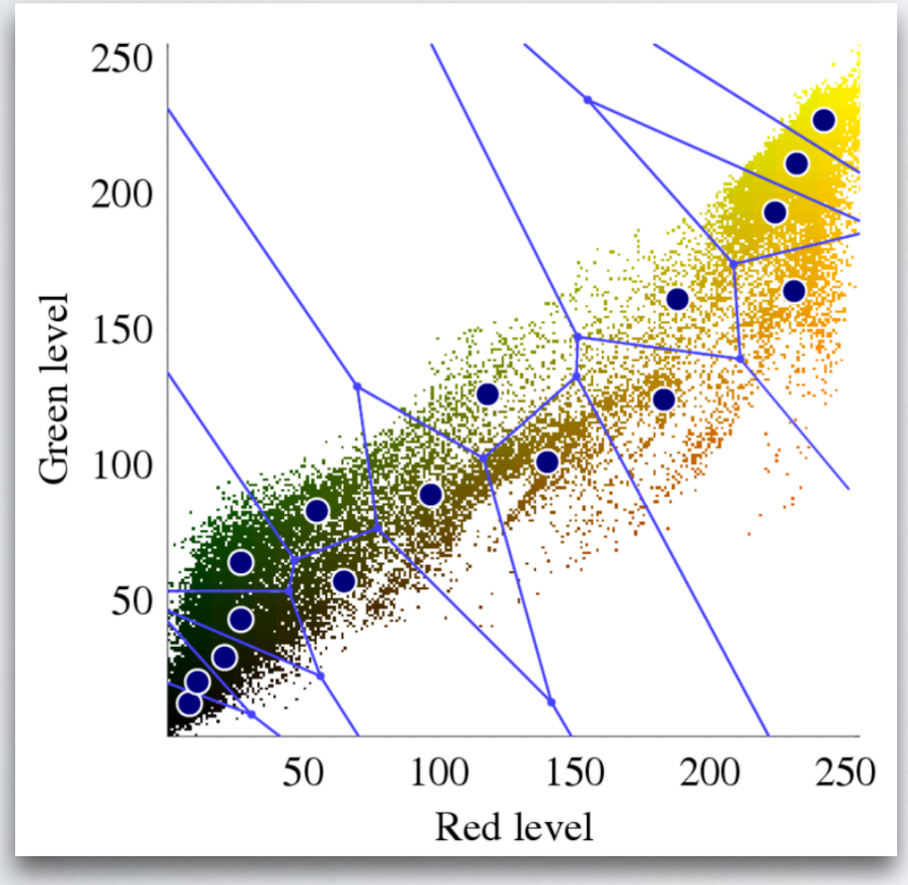


IQ (source)

- A simple example
- Like color mapping, you can remap position/spatial input
- In general, ordinarily, we have some **output = f(position)**
- However, we can arbitrarily modify the input position:
- output = **f(other_f(position))**
- More on spatial domain transforms from IQ

K-MEANS COLOR COMPRESSION

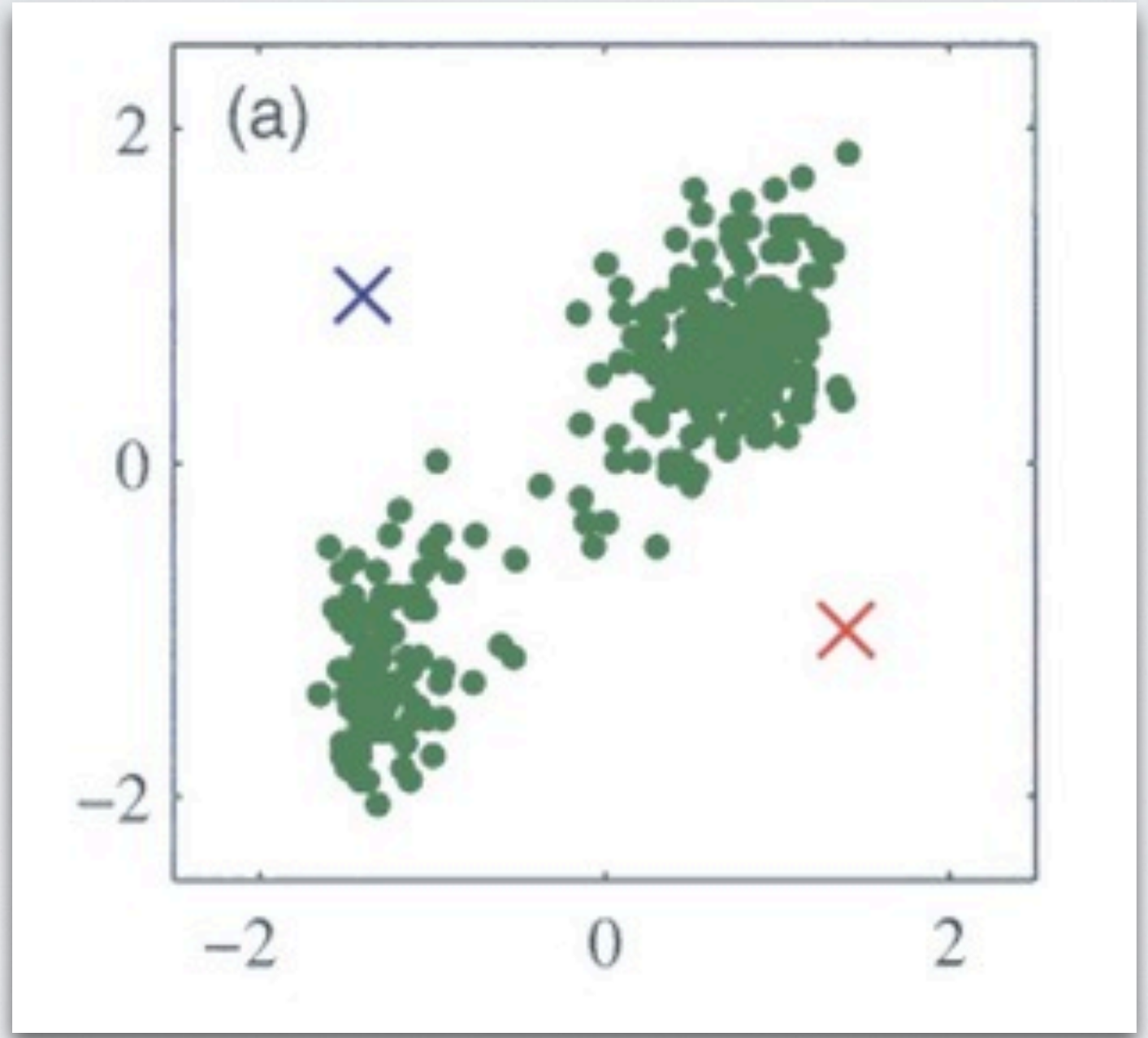
Dzcoetzee (source)



- Want to reduce the number of colors in an image
- But want to minimize the distance from original colorization
- Well, if we were reducing to a single color, we'd use the average of all pixel colors
- Need a way to find k averages, for compression to k colors.
- We can use the k-mean algorithm: clustering technique applicable in many domains. Works in virtually any feature space

K-MEANS COLOR COMPRESSION

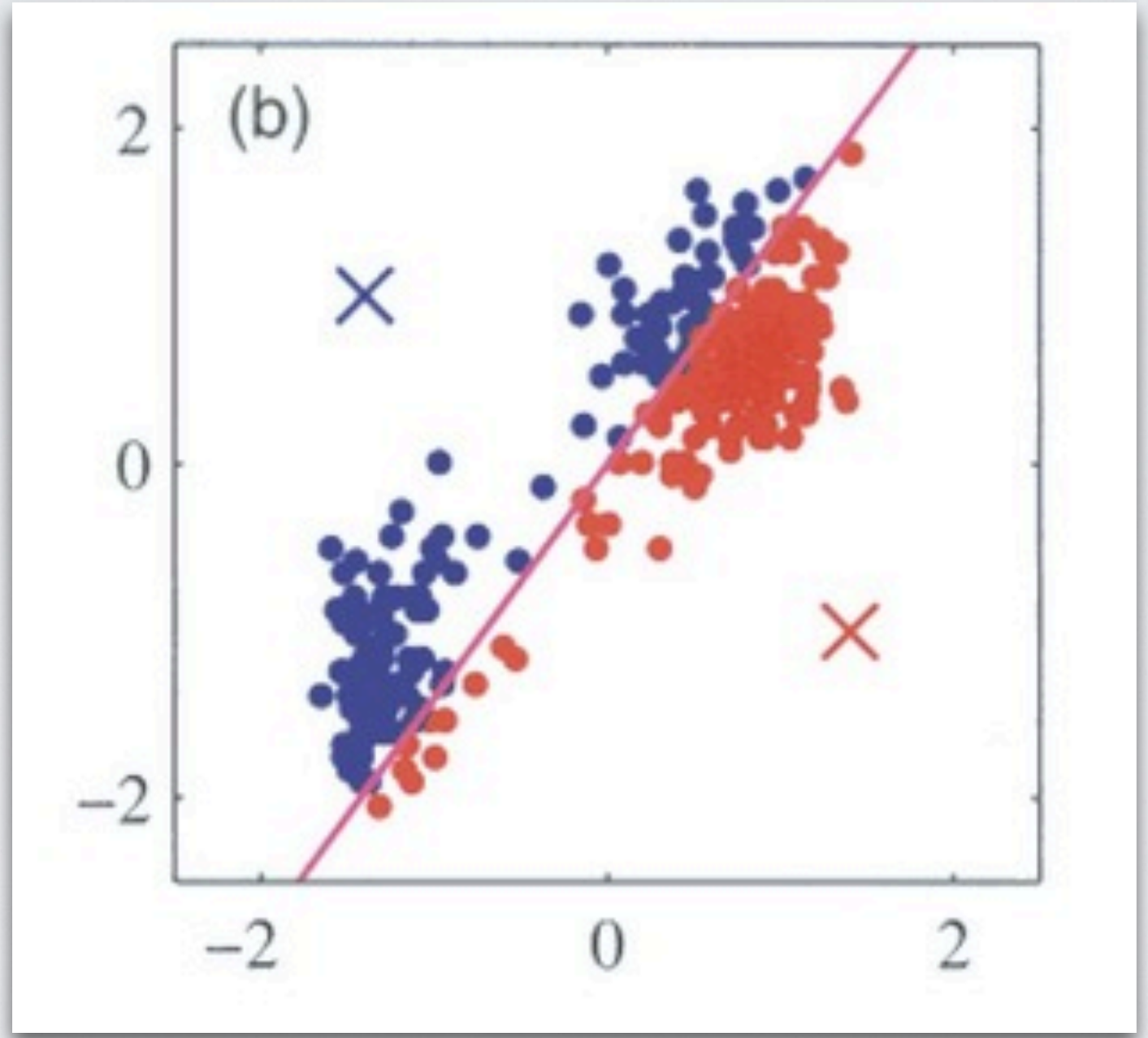
Initialize with k randomly-selected centroids



Bishop (source)

K-MEANS COLOR COMPRESSION

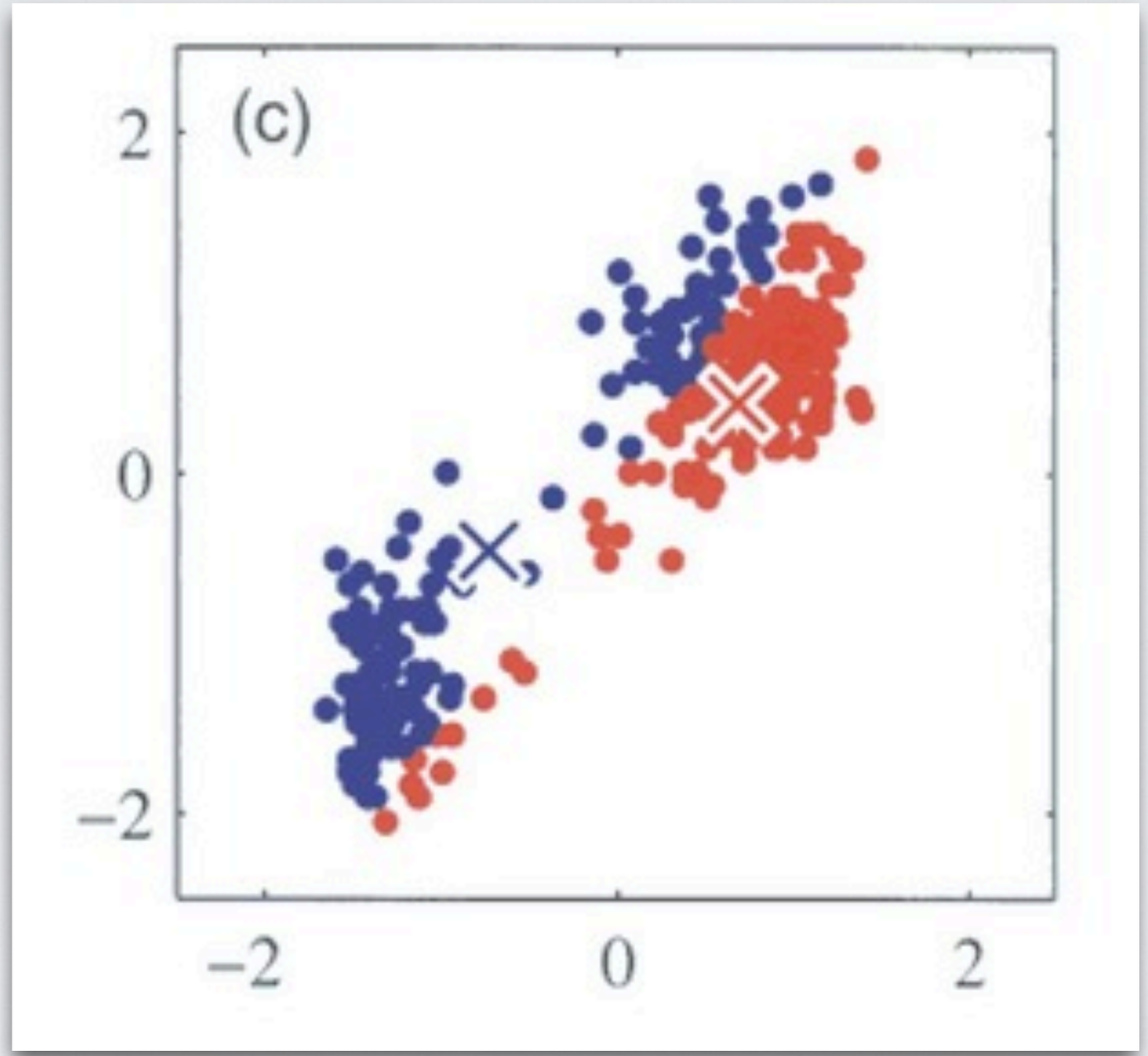
Assign every point to a cluster based on distance to centroid



Bishop (source)

K-MEANS COLOR COMPRESSION

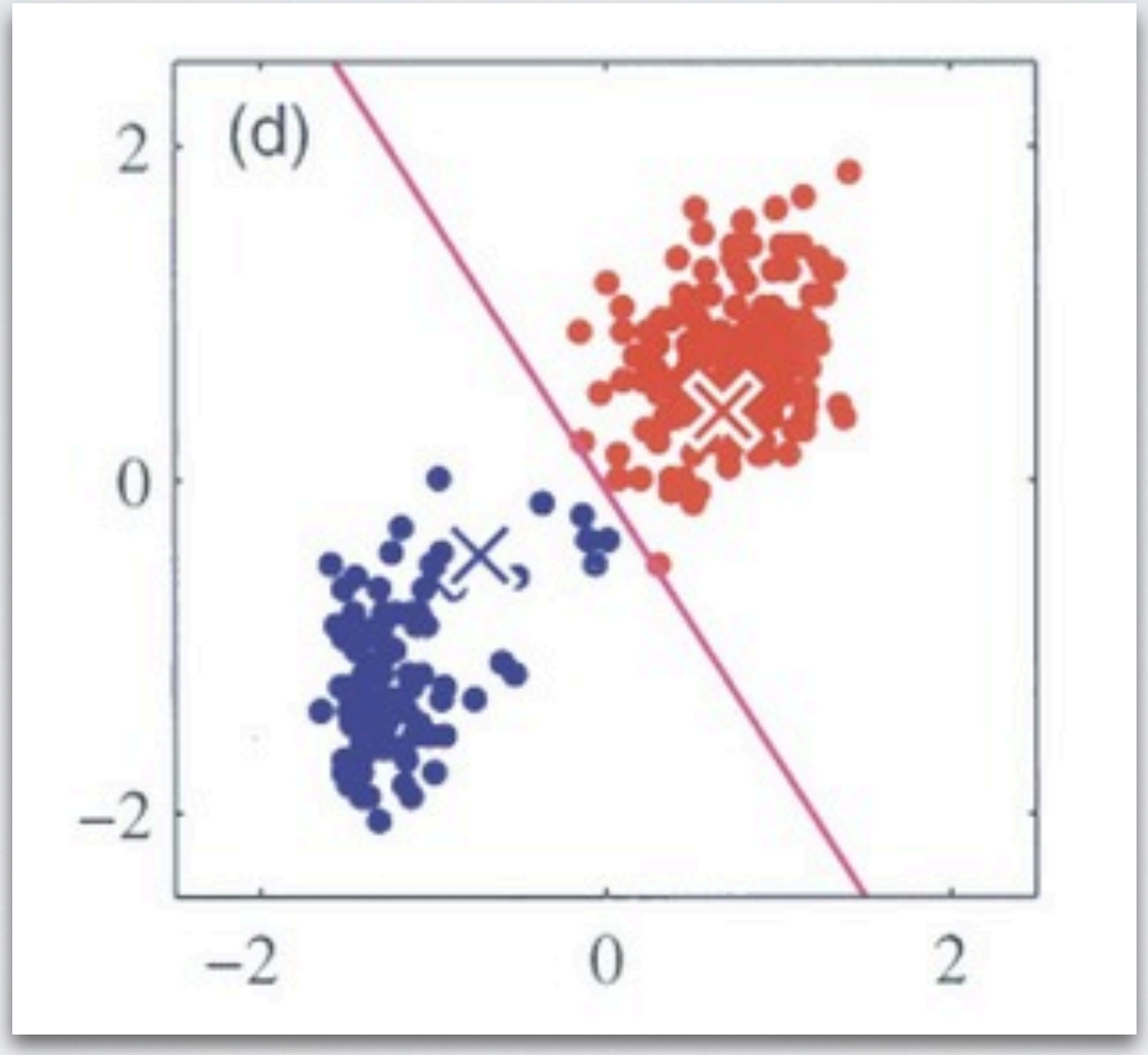
Per cluster, chose new centroid that will reduce distance to all points in the cluster.



Bishop (source)

K-MEANS COLOR COMPRESSION

Given the new centroids, reassign all points to a cluster by distance again.



Bishop (source)

K-MEANS COLOR COMPRESSION

Original

k = 16

k = 8

k = 4

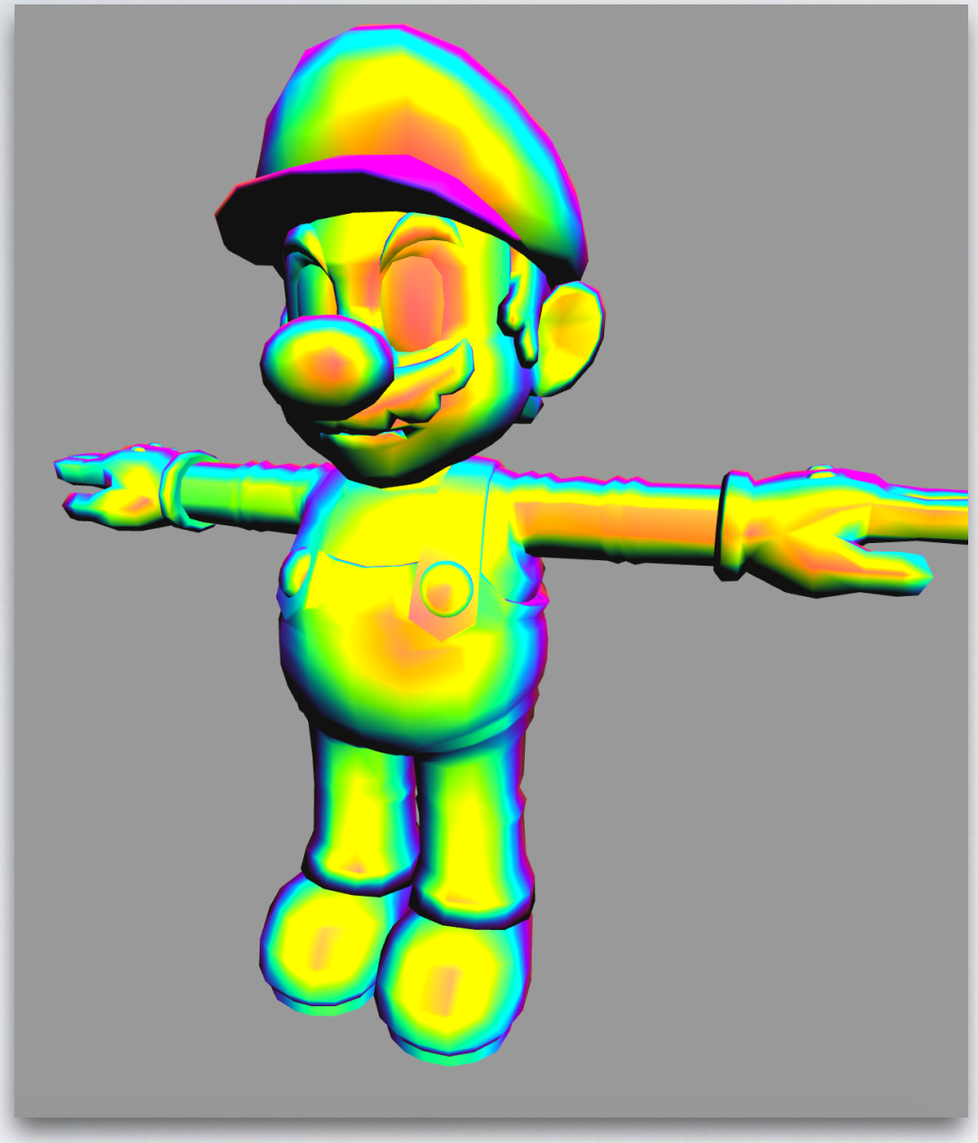
IN SUMMARY

- We introduced a lot of random shading and image processing techniques really fast!
- Graphics is full of mapping functions
    - By remapping color spaces, we can create cool effects
    - You can use any combination of existing attributes as parameters to some modification function, eg. map normals or look vector or darkness to some output space.
- Highlights
    - Gaussian blur - use distance-sensitive averaging to smooth
    - Toon shading - discretize your output color domain
    - Lit sphere - fake a reflectance model with a simple texture read
- In conclusion, there are too many cool effects to study! Take this as inspiration to experiment

REFERENCES

- Papers
    - Lit Sphere
    - Non-photorealistic Rendering in Chinese Painting of Animals
- Helpful articles
    - Intro to color theory
    - Intro to edge/outline detection
    - Intro to gaussian blur algorithm And another!
    - IQ's color palettes / reference implementation / Unity implementation
    - Huge collection of non-realistic graphics references
    - Procedural color palette ideas
- Textbook
    - Machine Learning reference (go big or go home!)

ASSIGNMENT



- Implement a variety of fun visual effects, in both world space and screen space shaders