Photoshop: Under the Hood

History

- First paint program: SuperPaint (1973)
- By Richard Shoup at Xerox PARC
- Photoshop was created in 1988
- Authors: Thomas and John Knoll (brothers)
- Adobe distributes program (1990)
- Adobe purchased rights in $34 million (1995)

Paint Programs

- Represent images as grids of pixels
- Image has finite resolution (e.g. 1280 x 1024)
- Often used for touching up photos
- Also used by artists to paint from scratch

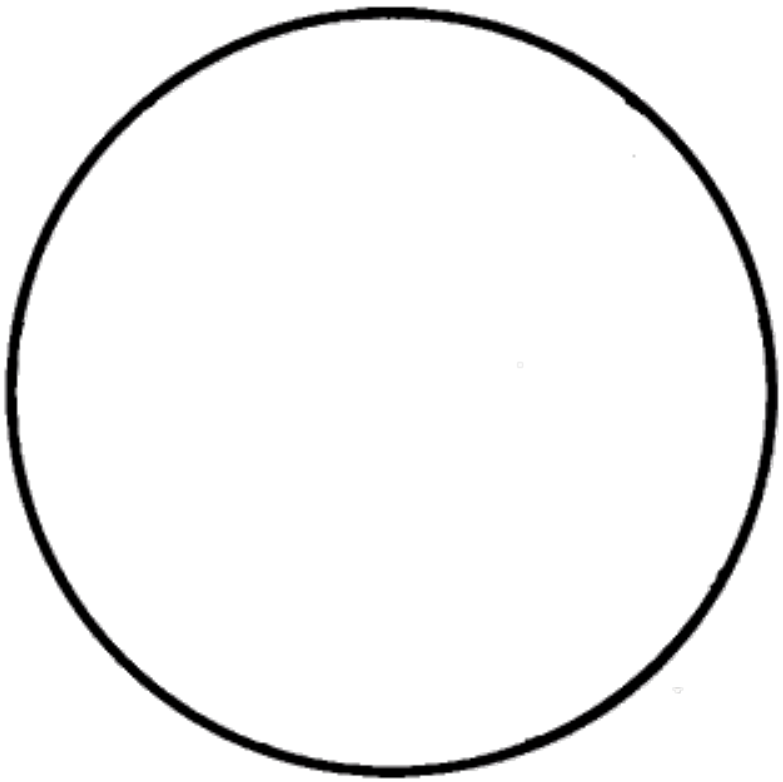
Popular Paint Programs

- Photoshop
- Gimp
- Corel Painter
- Procreate
- Art Rage
- Clip Studio Paint

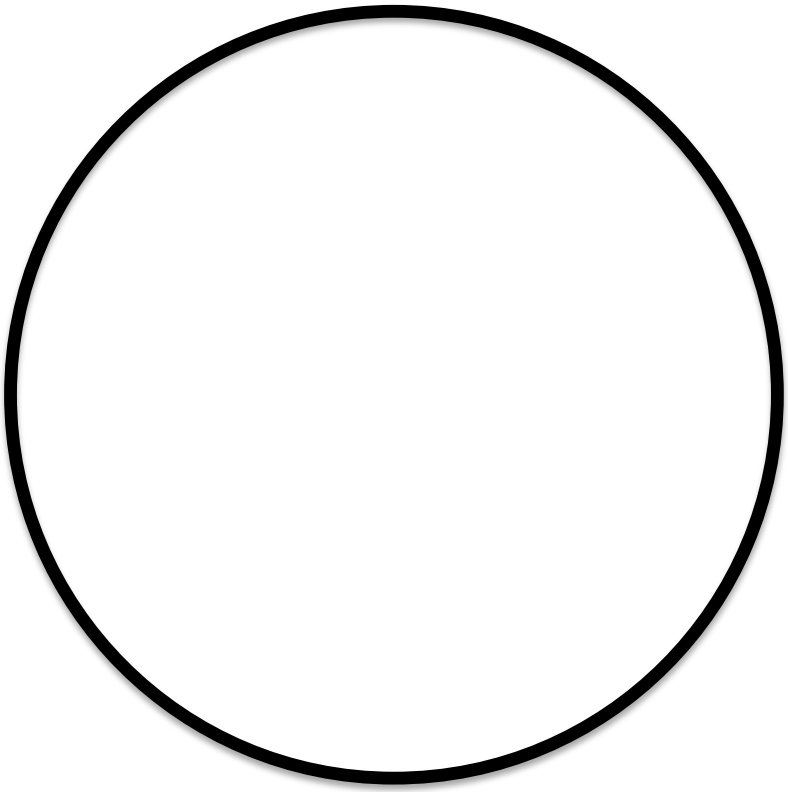
Drawing Programs

- Paint Program ≠ Drawing Program
- Drawing program represents image as collections of strokes (curves)
- Strokes: Arcs, Bezier curves, etc.
- Often called “Vector Graphics”
- Stroke **parameters** stored (e.g. circle center)
- Can zoom without loss of quality
- Illustrator and Inkscape are popular examples
- PowerPoint also includes drawing tools

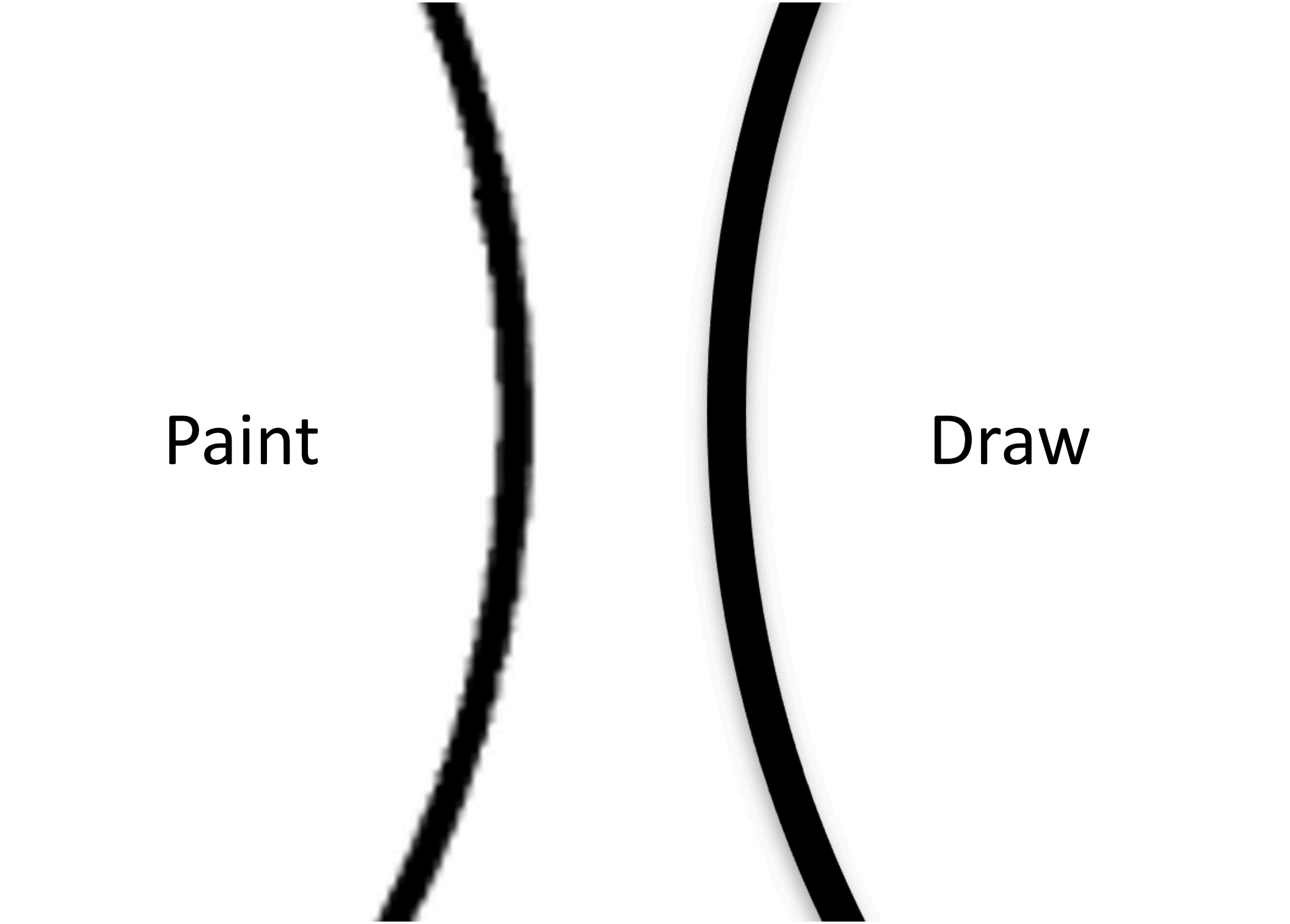
Paint vs Draw



Pixels



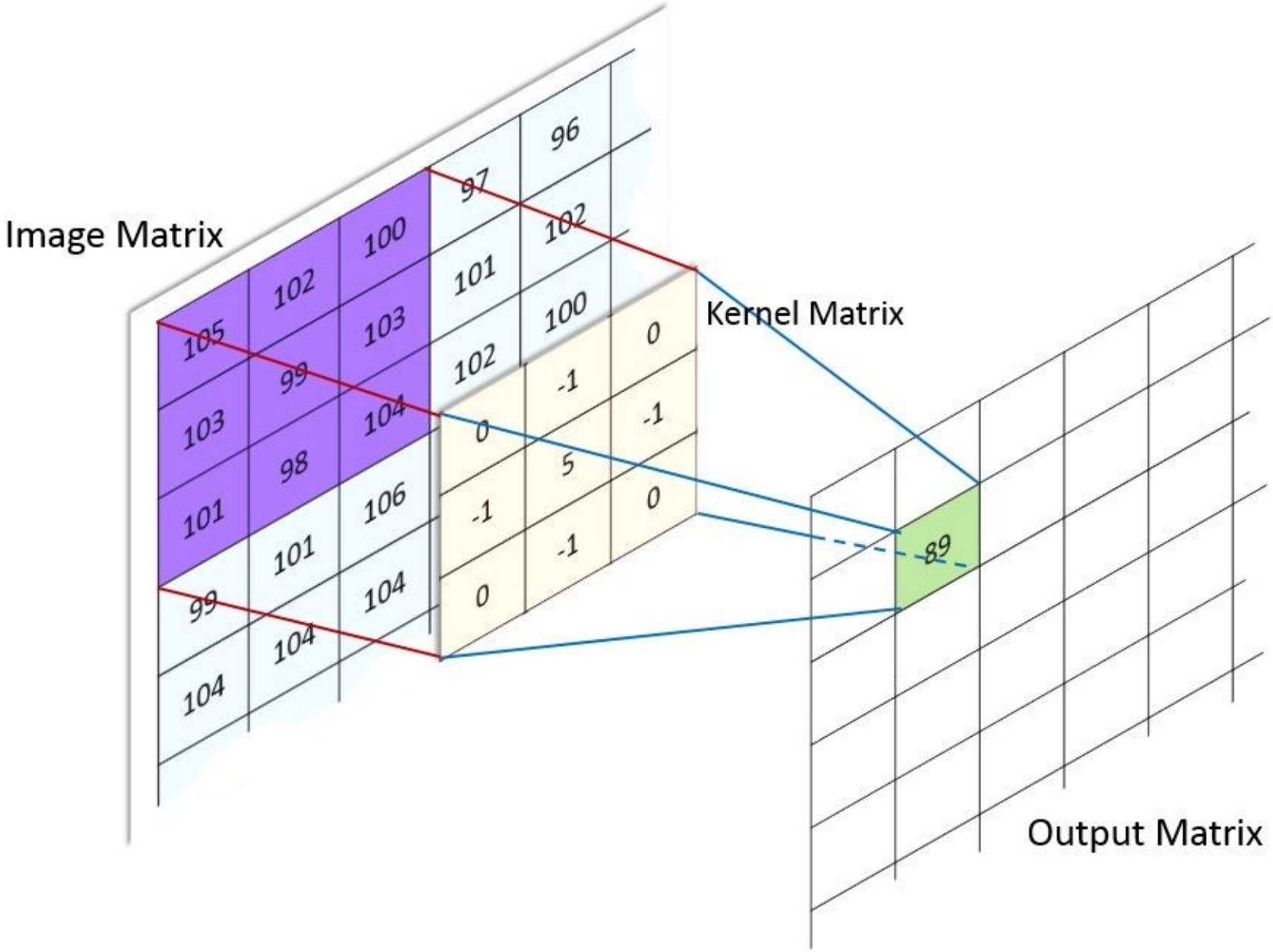
Parameterized Circle


Paint
Draw

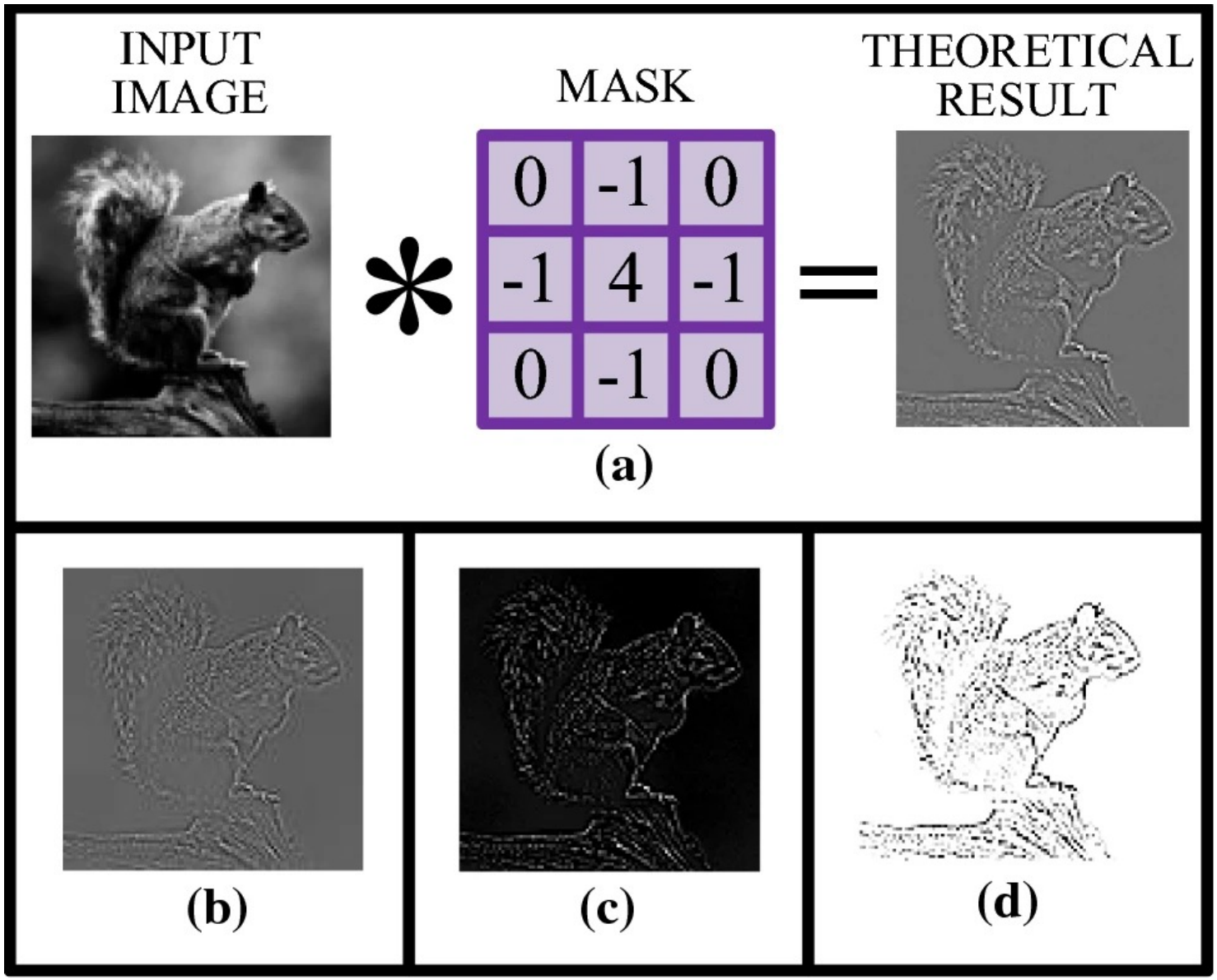
Filters and Convolution

- A filter changes image pixels in specific way
- Filtering is often done with a *convolution*
- Convolution is weighted sum of nearby pixels
- Weights say how nearby colors are combined
- Examples: edge detection and blur

Convolution



Edge Detection: Convolve with Laplacian



Blur: Convolve with Gaussian

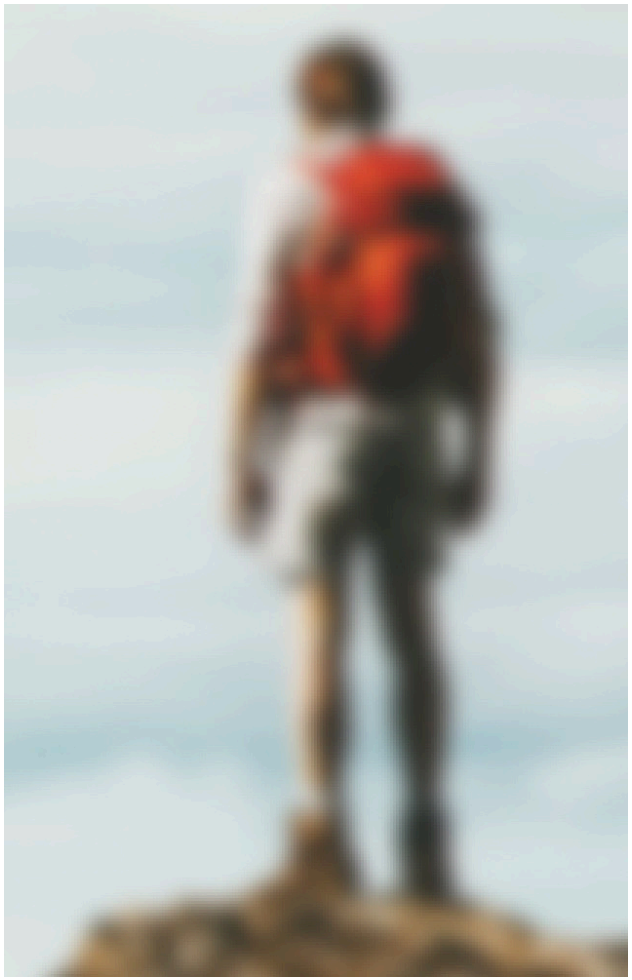
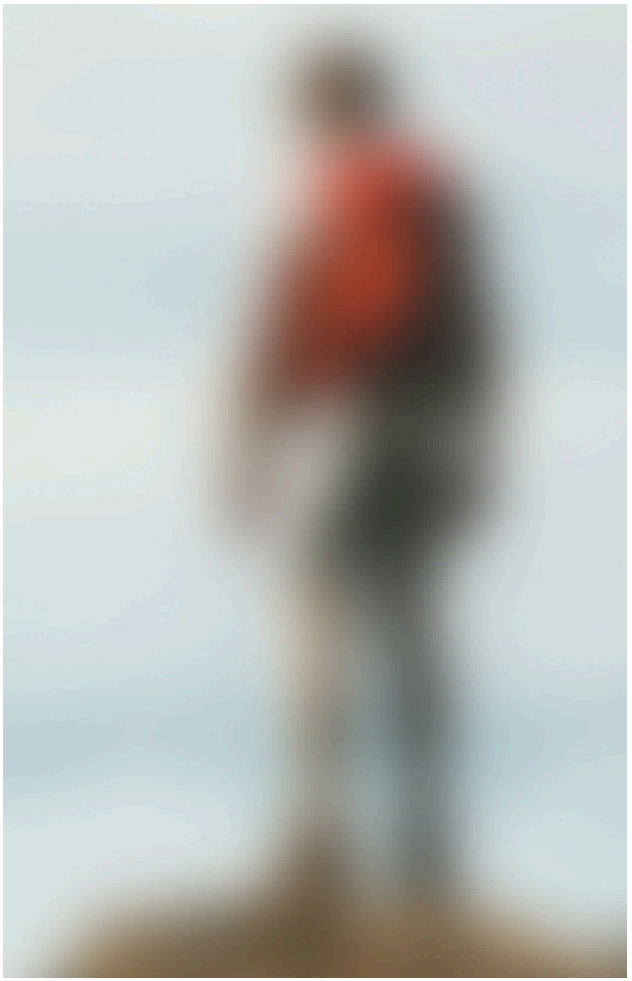
1/16

1	2	1
2	4	2
1	2	1

1/273

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

Blur Results

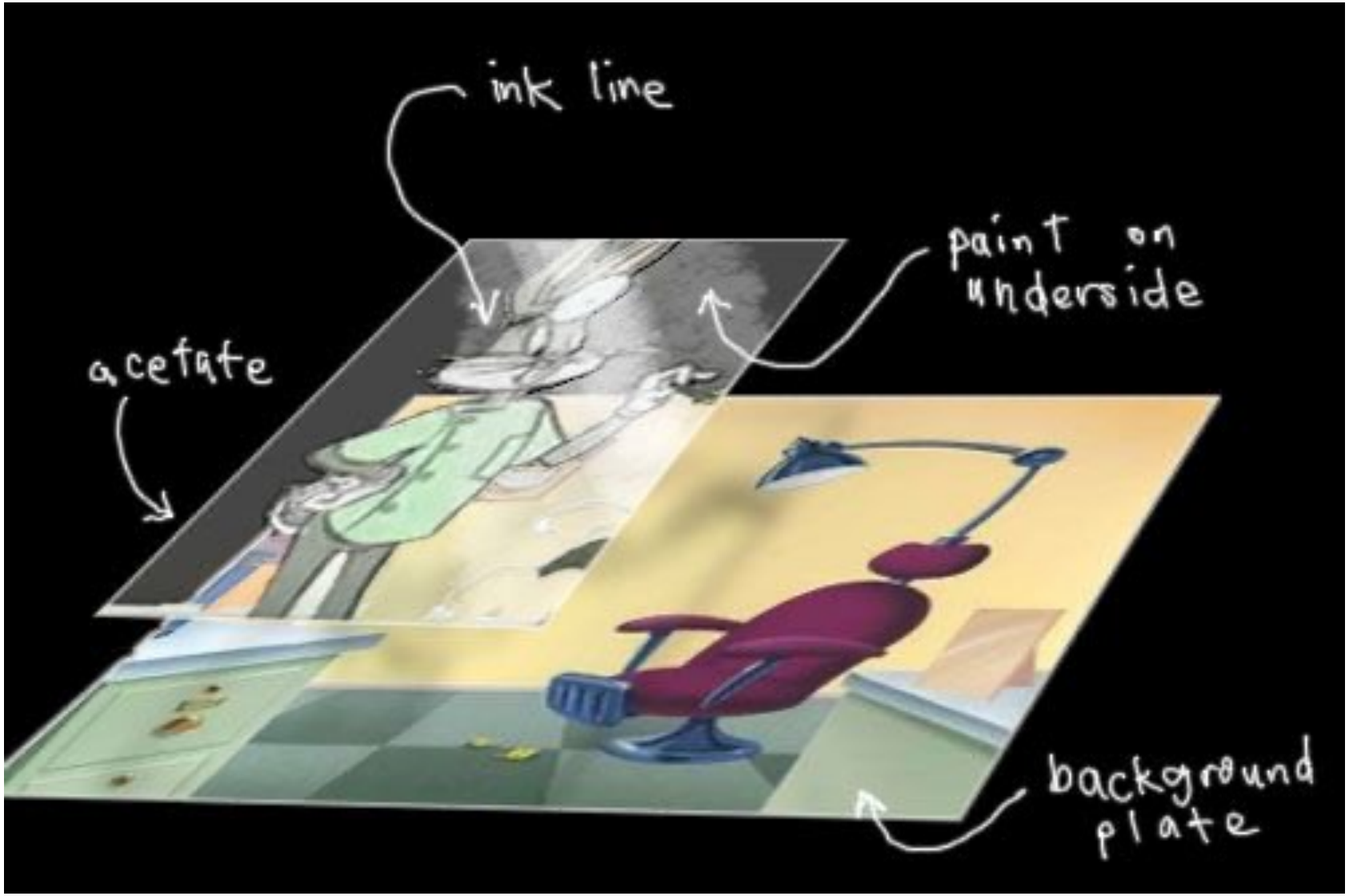



Demo (filters)

Pixels and Layers

- Photoshop represents image as **Layers**
- Each layer contains grid of pixels
- Each pixel has color (r,g,b,α)
- Alpha specifies transparency / opacity
- Where one layer is transparent, see thru to next layer
- Similar to old style cel animation

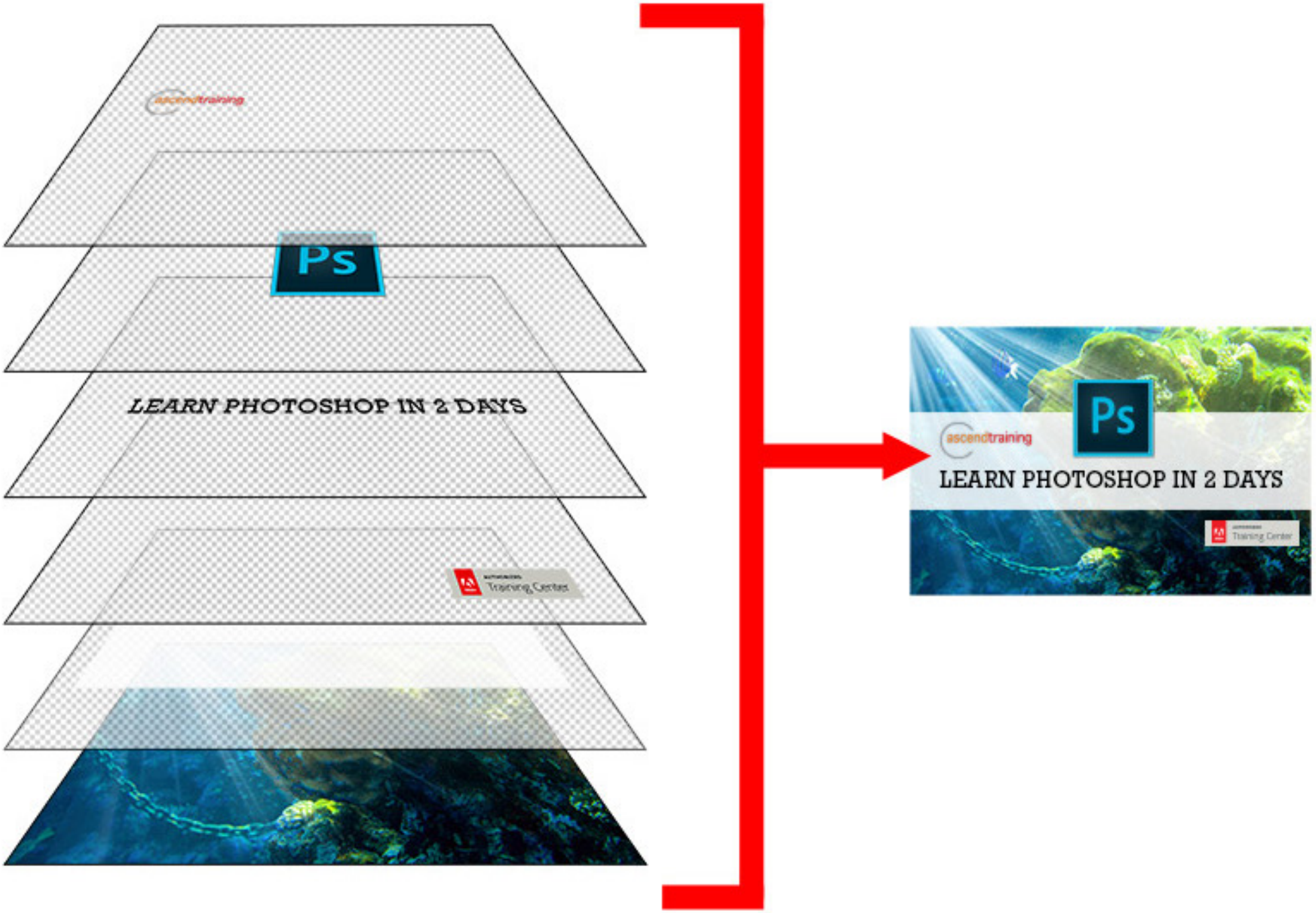
Cel Animation



Composition Equation

- Alpha = 0, totally transparent pixel
- Alpha = 1, totally opaque
- Alpha = 0.5, half color from lower layer
- Layer arithmetic guided by simple equation
- Nearly identical to volume composition
- Calculated from per-pixel colors & alpha

Final Color = alpha * top_layer + (1 – alpha) * next_layer


ascendtraining
Ps
LEARN PHOTOSHOP IN 2 DAYS
Training Centers
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Training Center

Special Layers

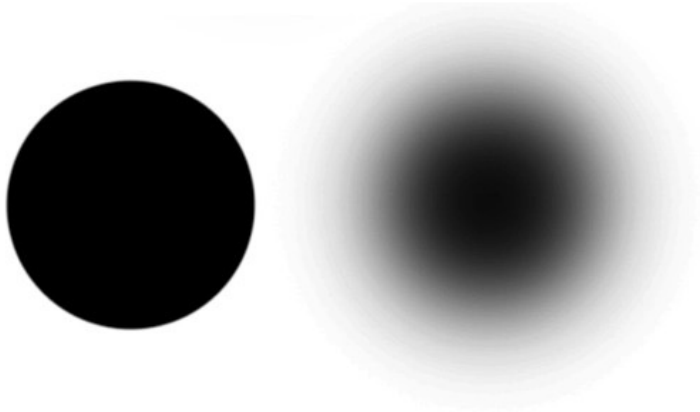
- Special layers are operators (not pixels)
- Used to adjust colors:
  - Brightness
  - Contrast
  - Blue / Yellow balance
  - Etc.

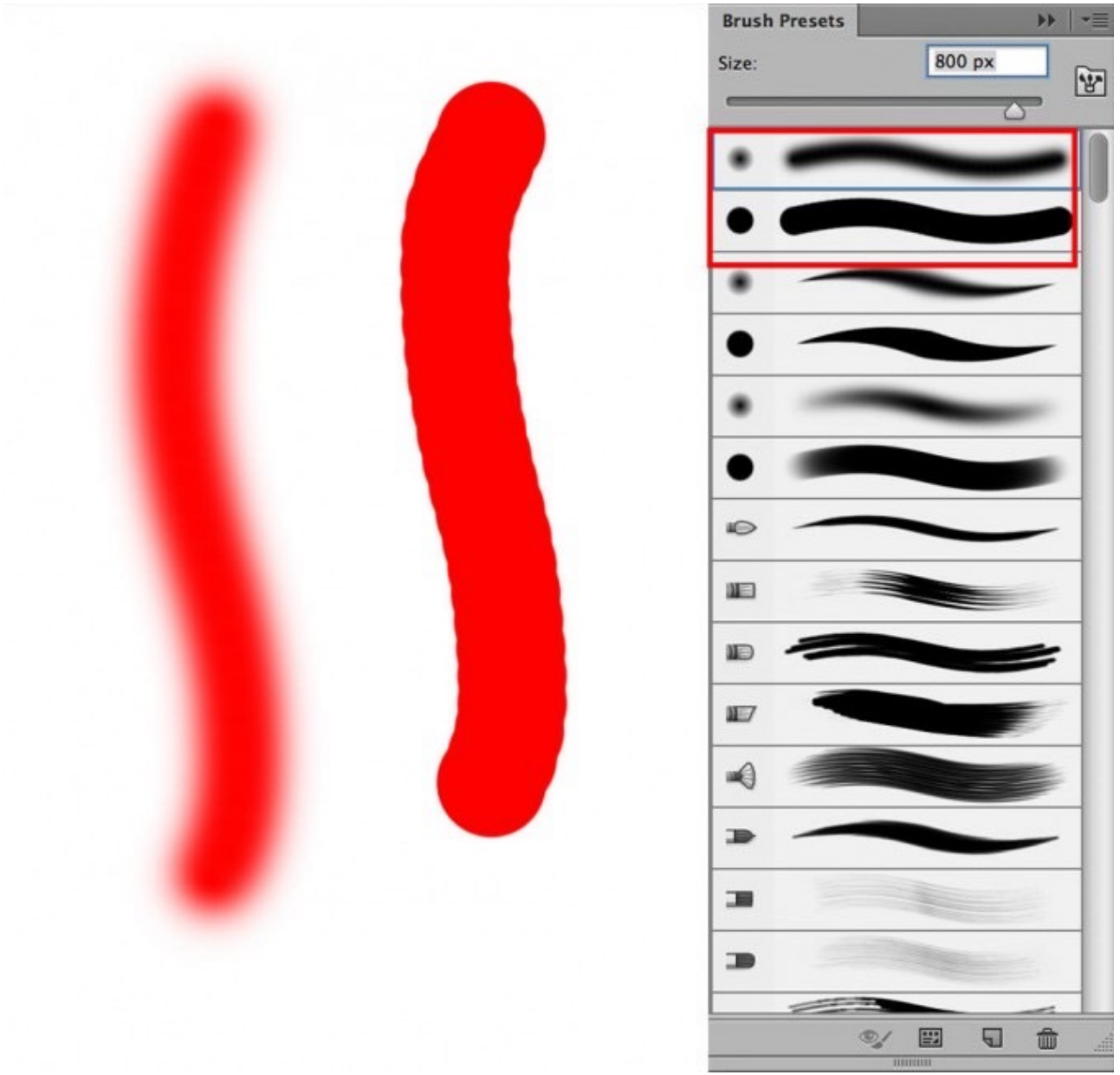
Painting

- Use painting metaphor to modify pixel values
- Brush tool to add “paint”
- Brush stroke places colors onto a layer along user’s path

Painting

- Brush is actually a small image
- Brush can be hard-edged or soft
- Soft parts given by alpha values
- Brush doesn’t have fixed color
- Brush color comes from color selector




Brush Presets
Size:
800 px

Demo (layers, painting)

Many Other Tools

- Too Many Tools to Cover!
- Will concentrate on a few:
  - Selection
  - Hole Filling
  - Image Warping (Liquify)

Selection

- Can select a portion of a layer
- Operations on selected regions:
  - Cut / copy / paste
  - Transform: scale, translate, rotate
  - Filter: blur, sharpen, lighten, darken

Selection

- Several selection tools:
  - Lasso, polygonal lasso, magnetic lasso
- Most advanced methods are image-aware
- Image-aware selection looks for *edges*
  - High contrast edges
  - Sharp color changes
- Image-aware selection based on **Active Contours**

Active Contours

- Paper by Kass, Wiktin, Terzopoulos (1988)
- Paper has over 26,000 citations
- Contour is usually curve similar to Bezier
- Control point positions guided by:
  - User dragging
  - Maintaining smoothness (minimal bending)
  - Attraction to image edges (image-aware)
- Balance these using energy formulation

Active Contours in Photoshop

- Used for Selection
- Magnetic Lasso Tool
- Quick Selection Tool

Demo (Selection)

Hole Filling

- Remove portions of photos
  - People
  - Blemishes
  - Telephone pole
  - Etc.
- Called **image inpainting**
- Several approaches used

Hole Filling

- Copy pixels from other parts of image
- Two Problems:
  - Match intensity when pixels are copied (especially at borders)
  - Decide which parts to copy from

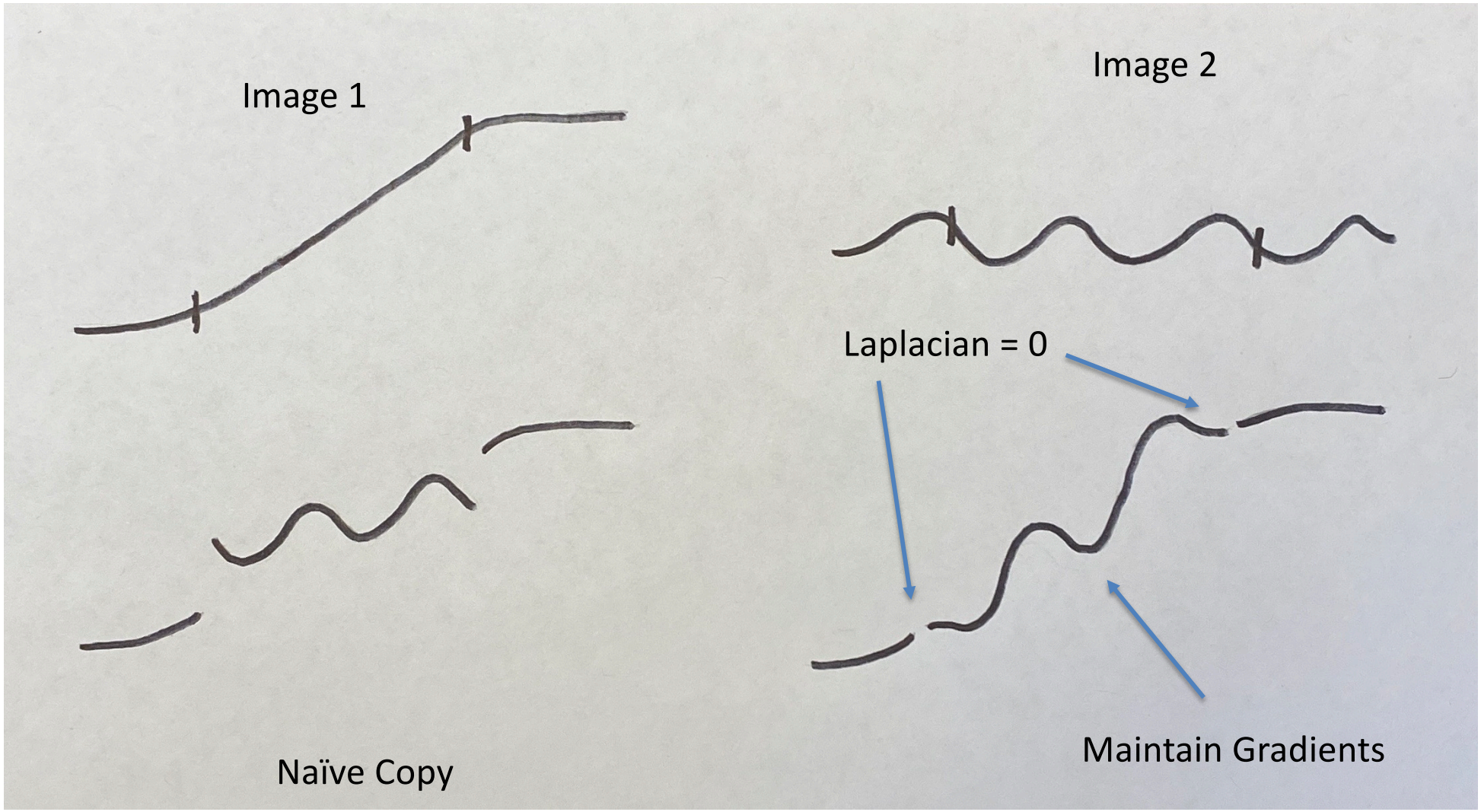
Poisson Image Editing

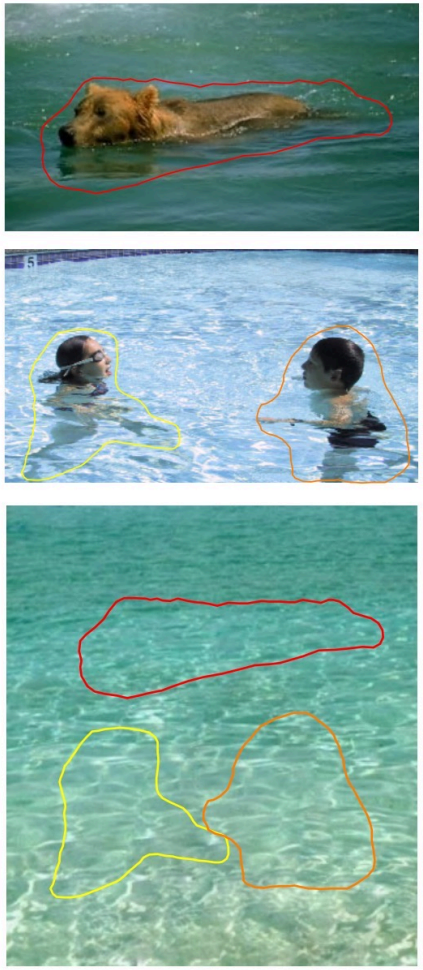
- Match source and destination intensities
- Key idea:
  - Match intensities at borders
  - Maintain local pixel contrast inside borders
- Do this by solving Poisson equation
- By Perez, Gangnet, and Blake (2003)
- Photoshop's "Patch Tool"

Poisson Image Editing

- Source and target regions need to match
- Source pixel contrasts give gradients (vectors)
- Target region gives boundary value constraints (scalar image intensities)
- Poisson equation matches both sets of constraints
  - Laplacian = 0 on boundary
  - Maintain intensity gradients inside region

Poisson Editing

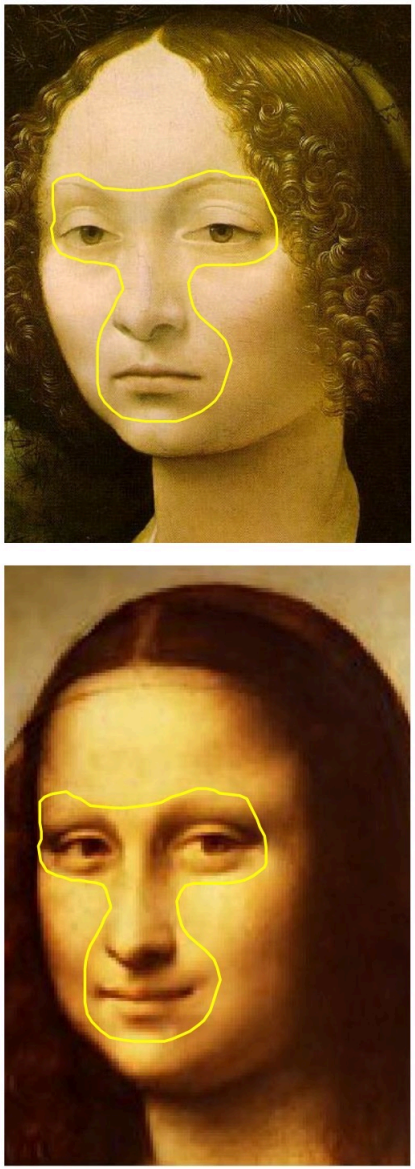




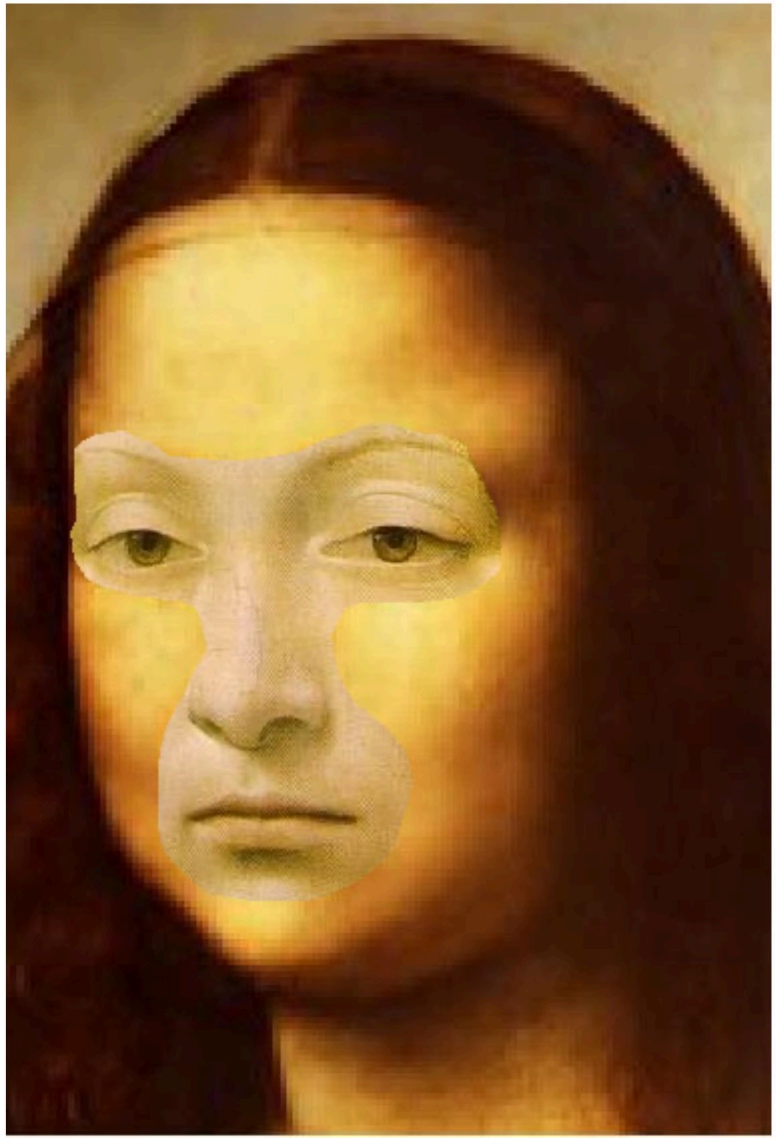
sources/destinations

cloning

seamless cloning



source/destination



cloning

seamless cloning

Patch Match

- Deciding where to copy from to fill in a hole
  - Human can choose
  - Algorithm can choose
- Patch Match is algorithm to pick good regions
- By Barnes, Shechtman, Finkelstein, Goldman (2009)
- Photoshop “Spot Healing Brush”

Patch Match

- Use **image patches** to decide what is good part to copy from
- Image patch is small region (e.g. 9x9 pixels)
- Compare colors between 9x9 regions (sum-of-squared-differences)
- For hole filling, look for good matches for edge of hole, then work inward
- Uses random tests to speed up process

Patch Match

(d) input

(e) hole

(f) completion (close up)

Hole Filling Demo

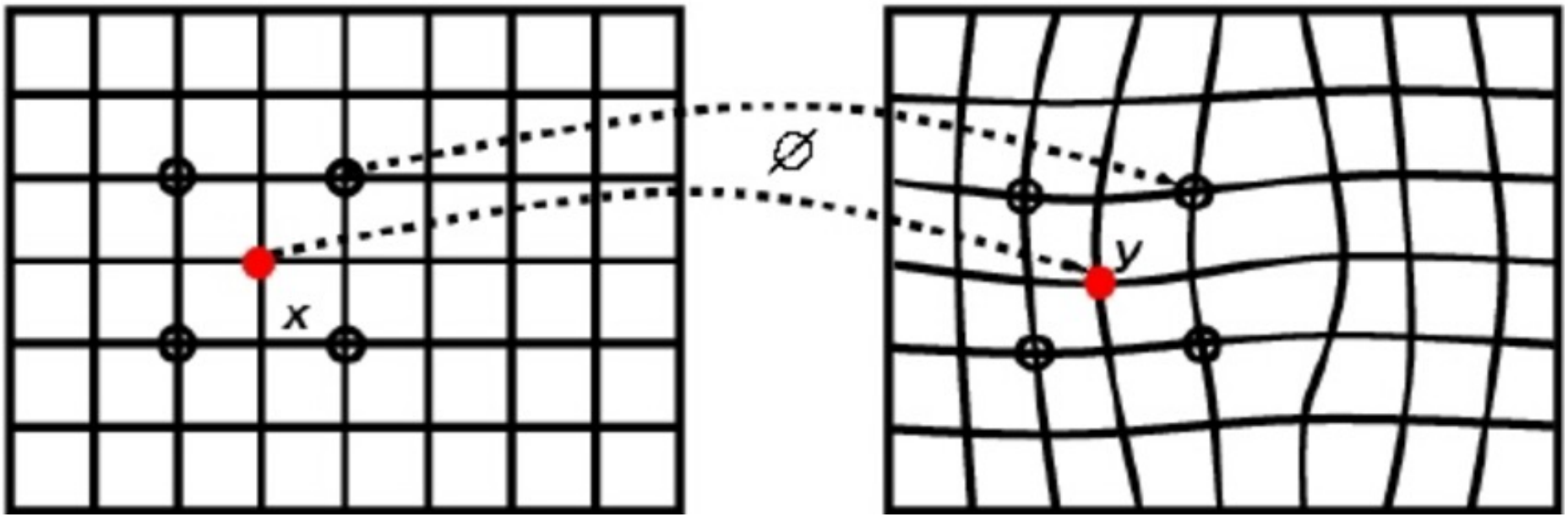
Image Warping

- Create image distortions (source -> target)
- Often described in two parts
  - Corresponding source and target landmarks
  - Region of influence around landmarks
- Several kinds of landmarks:
  - Points with radius
  - Line segments
  - Triangles
- Influence decreases with distance to landmark

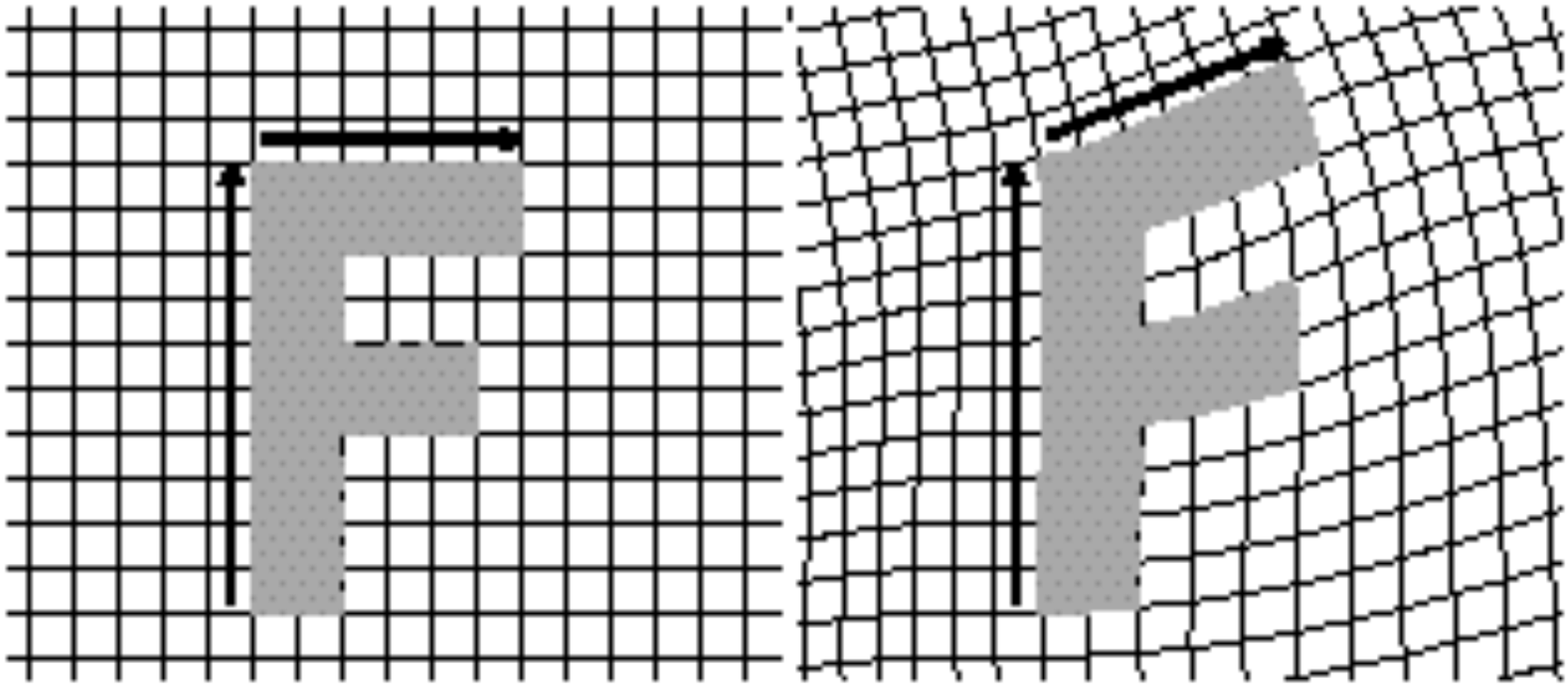
Image Warping

- Influence decreases with distance to landmark
- Influence functions often Gaussian (bell curve)
- Shape of influence usually called Radial Basis Function
- Many variations of this scheme

Point Landmarks



Line Segment Landmarks
(Beier & Neely, SIGGRAPH 1992)



Face Warping

- Computer can detect face landmarks
  - Eyes
  - Nose
  - Mouth
- Person then can use sliders to say how landmark positions change
- Gives real-time face warping

Liquify Demo

New Tools: AI Techniques

- Deep neural network techniques on the rise
- Neural nets can modify an image
  - artistic filters
  - content-aware hole filling (inpainting)
- Neural nets can create images from scratch
  - User provides description (“prompt”)
  - Network creates new image in seconds
- Final lecture will discuss this in detail

Demo?

Summary

- Layers are grids of pixels with color and alpha
- Combining of layers is controlled by alpha
- Brushes are small images that modify a layer
- Smart selection done using active contours
- Hole filling by Poisson equation
- Warping by moving landmarks

End