Finishing Up Assignment 1: Image Processing

COS 426: Computer Graphics (Spring 2020)

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Course Logistics Update

- New course website incoming!
  - Preview at https://reillybova.github.io/COS426-Website/
  - Should have everything, but may be slightly buggy as we work out kinks
  - If you notice any problems, please make a public Piazza post under the "website" folder
- Web Framework specs (for those interested):
  - ReactJS for state-based logic and modularity
  - MaterialUI to build a Material Design compliant interface
  - GatsbyJS to compile the React App to static server files (allows us to host site as a normal webpage, and makes it blazing fast)
  - Content generate from Markdown

Fill out the Assignment 0 Feedback Form

Do this **now** — it takes less than a minute:

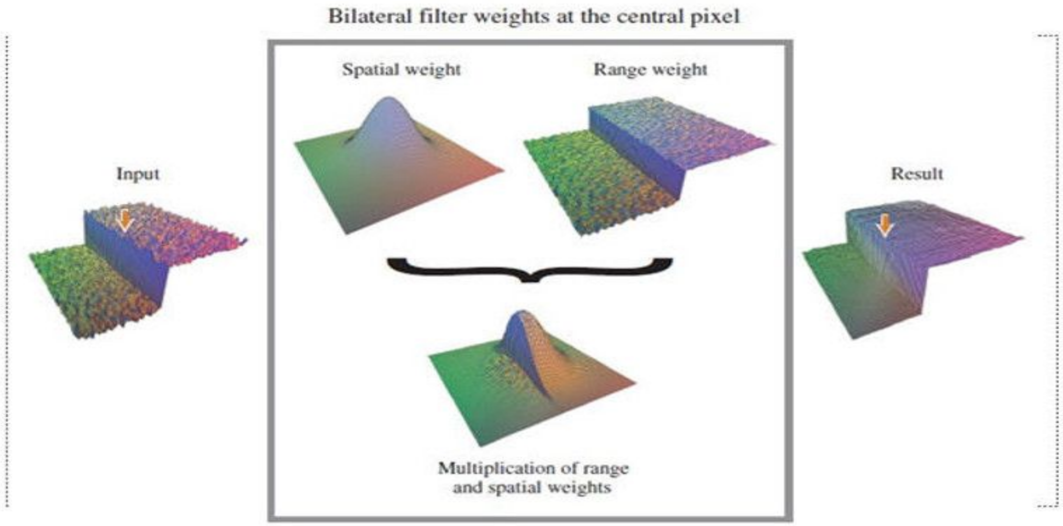
- https://forms.gle/o2ea1iJ978zY6Kd78

An Update on the Bilateral Filter

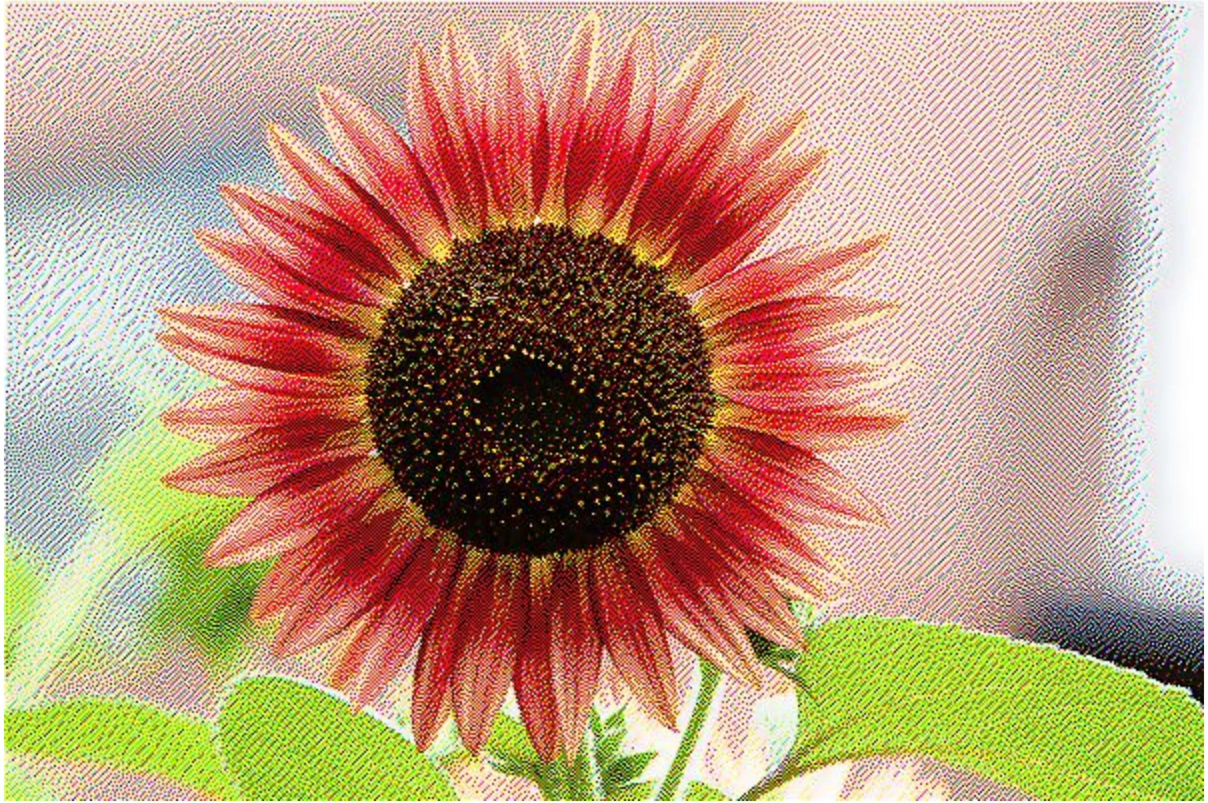
- Compute color distance in RGB space, scaled to [0, 255].

Spatial distance component   Color distance component

$$w(i,j,k,l) = e^{\left(-\frac{(i-k)^2+(j-l)^2}{2\sigma_d^2} - \frac{\|I(i,j)-I(k,l)\|^2}{2\sigma_r^2}\right)}$$

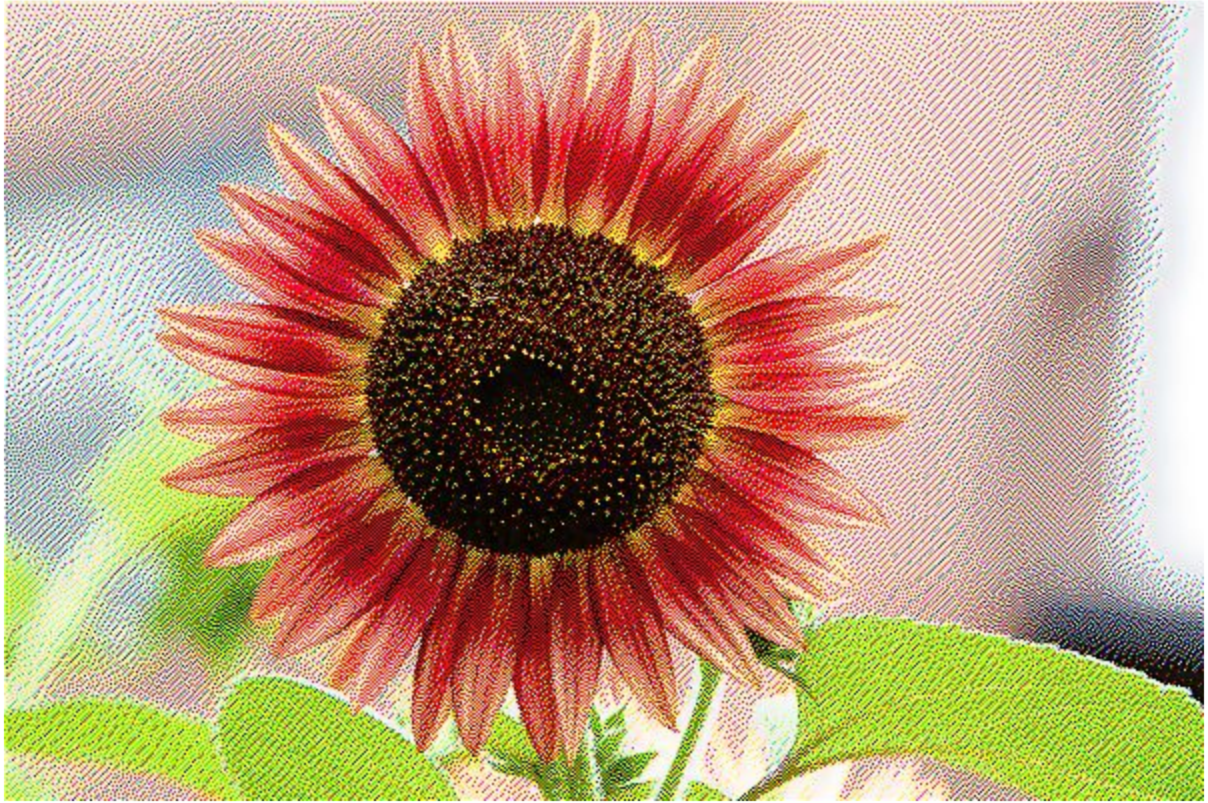


A Familiar Pattern



Notice anything familiar about the pattern?

Why Dither?



It’s a Floyd-Steinberg dither over RGB channels (1 bit each)!

This filter was often used to compress web GIFs — look for the artifact in old-school animations!

Ordered dithering

Pseudo code for n-bit case:

$$m = 4,\ D = \begin{bmatrix} 15 & 7 & 13 & 5 \\ 3 & 11 & 1 & 9 \\ 12 & 4 & 14 & 6 \\ 0 & 8 & 2 & 10 \end{bmatrix}$$

```
i = x mod m
j = y mod m
err  = I(x, y) - floor_quantize(I(x, y)))
threshold = (D(i, j)+ 1) / (m^2 + 1)
if err > threshold
    P(x, y) = ceil_quantize(I(x, y)))
else
    P(x, y) = floor_quantize(I(x, y)))
```

- `floor_quantize(p) = floor(p * (2^n-1)) / (2^n-1)`
- `ceil_quantize(p) = ceil(p * (2^n-1)) / (2^n-1)`

n=1 example

Picking up where we left off last week...

Luminance
- Brightness
- Contrast
- Gamma
- Vignette
- Histogram equalization

Color
- Grayscale
- Saturation
- White balance
- Histogram matching

Filter
- Gaussian
- Sharpen
- Edge detect
- Median
- Bilateral filter

Dithering
- Quantization
- Random dithering
- Floyd-Steinberg error diffusion
- Ordered dithering

Resampling
- Bilinear sampling
- Gaussian sampling
- Translate
- Scale
- Rotate
- Swirl

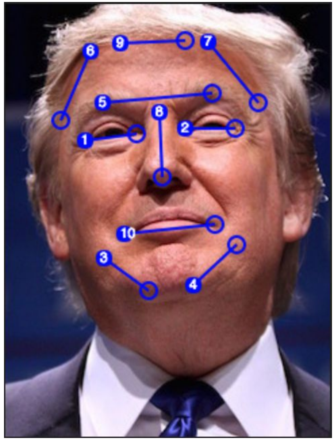
Composite
- Composite
- Morph

This week's precept will focus specifically on this topic

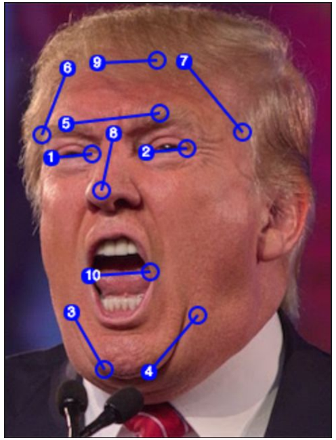
Morph

- Basic concepts
  - transform the background image to the foreground image
  - alpha = 0: show background
  - alpha = 1: show foreground
  - alpha is the blending factor / timestamp
- General approach
  - specify correspondences (morphLines.html)
  - create an intermediate image with interpolated correspondences (alpha)
  - warp the background image to the intermediate image
  - warp the foreground image to the intermediate image
  - blend using alpha

Interpolate Morph Lines



Background Image



Foreground Image

current_line[i] = (1 – alpha) * background_lines[i] + alpha * foreground_lines[i]

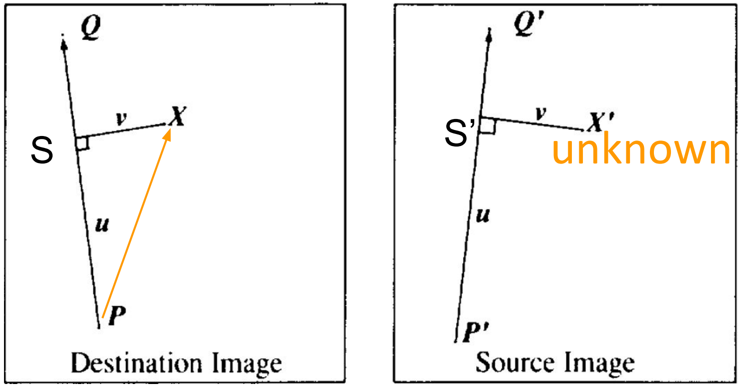
Warp Image

- scalar $u = \frac{(X-P)\cdot(Q-P)}{||Q-P||^2}$ = Projection of PX onto PQ
- scalar $v = \frac{(X-P)\cdot Perpendicular(Q-P)}{||Q-P||}$ unit vector
- $X' = P' + u\cdot(Q'-P') + \frac{v\cdot Perpendicular(Q'-P')}{||Q'-P'||}$ unit vector
- $dist = shortest\ distance\ from\ X\ to\ PQ$
  - 0 <= u <= 1: dist = |v|
  - u < 0: dist = ||X – P||
  - u > 1: dist = ||X – Q||
- $weight = (\frac{length^p}{a+dist})^b$
  - we use p = 0.5, a = 0.01, b = 2

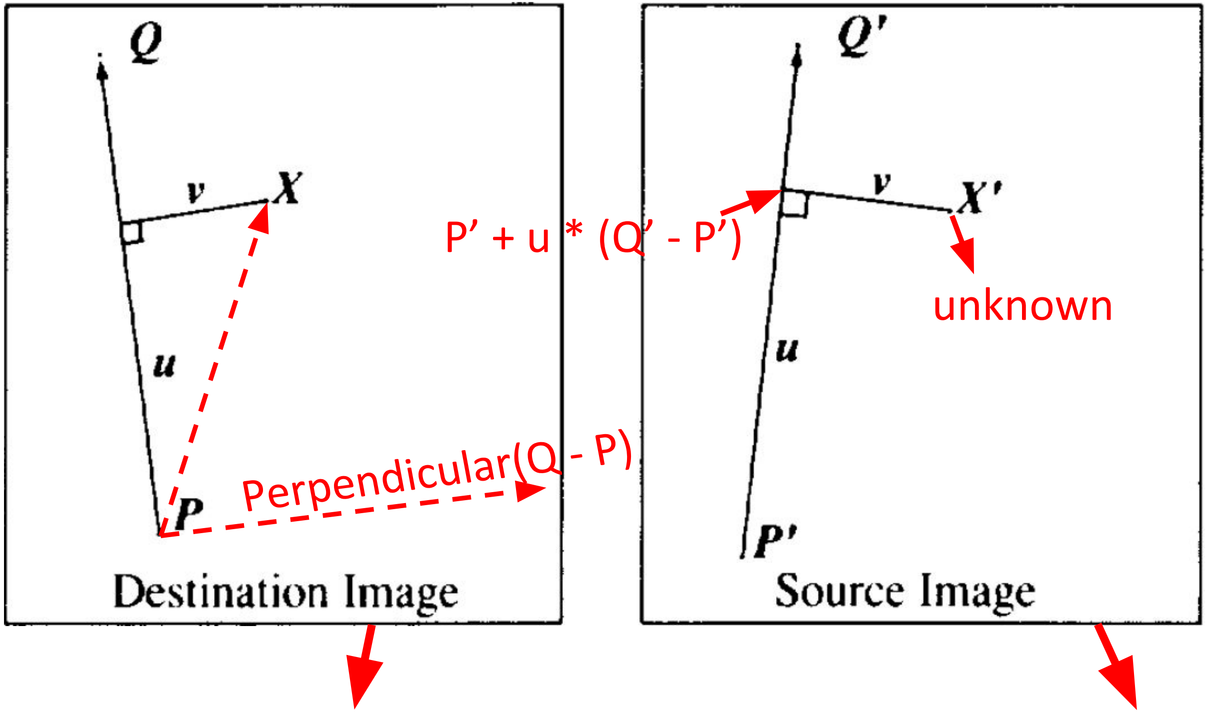
Contribution (weight) of line segment PQ to the warping of X's location

If Q - P = (x, y),
Perpendicular(Q – P) = (y, -x)

S' = P' + u * (Q' - P')



Warp Image



Let S be the projection point of X onto PQ

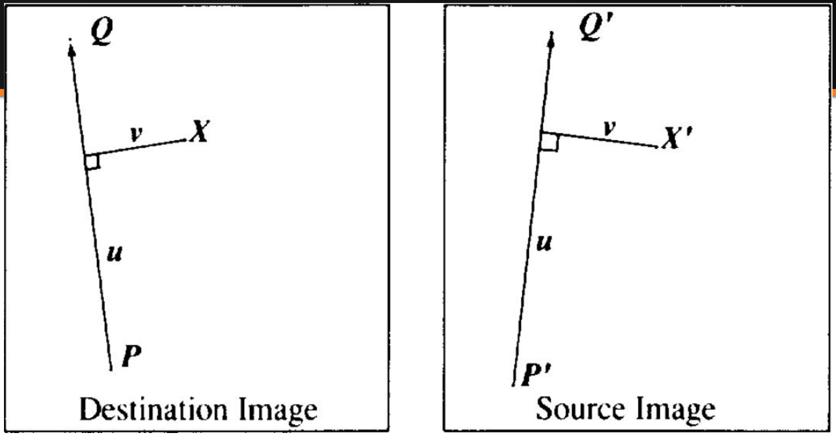
u = fraction of SP's signed length over PQ's absolute length

v = X's signed distance to PQ, or to say, signed length of SX L

Warped background or foreground (currently black)

Pixel source (background or foreground)

Warp Image



For each pixel X in the destination

  $DSUM = (0,0)$

  $weightsum = 0$

  For each line $P_i Q_i$

    calculate u,v based on $P_i Q_i$

    calculate X'_i based on u,v and $P_i'Q_i'$

    calculate displacement $D_i = X_i' - X_i$ for this line

    $dist$ = shortest distance from X to $P_i Q_i$

    $weight = (length^p / (a + dist))^b$

    $DSUM \mathrel{+}= D_i * weight$

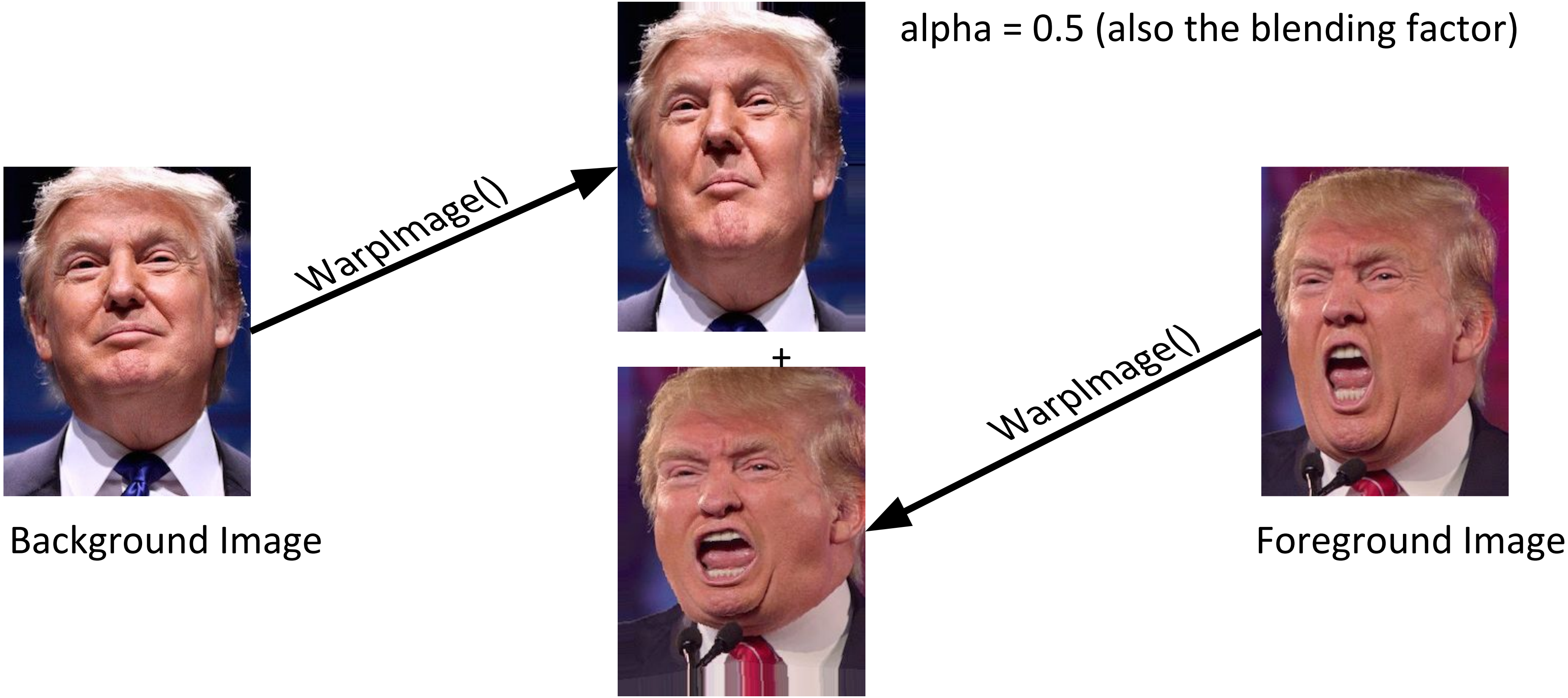
    $weightsum \mathrel{+}= weight$

  $X' = X + DSUM / weightsum$

  destinationImage(X) = sourceImage(X')

Blending

alpha = 0.5 (also the blending factor)



Morph

```
GenerateAnimation(Image_0, L_0[…], Image_1, L_1[…])
begin
    foreach intermediate frame time t do
        for i = 1 to number of line pairs do
            L[i] = line t-th of the way from L_0 [i] to L_1 [i]
        end
        Warp_0 = WarpImage(Image_0, L_0, L)
        Warp_1 = WarpImage(Image_1, L_1, L)
        foreach pixel p in FinalImage do
            Result(p) = (1-t) Warp_0 + t Warp_1

    end
end
```

Blending

alpha = 0.5 (also the blending factor)

Background Image

Foreground Image

Q&A