Image Resizing & Seamcarve

CS16: Introduction to Algorithms & Data Structures

Outline

- Image resizing
- Seamcarve

The New York Times

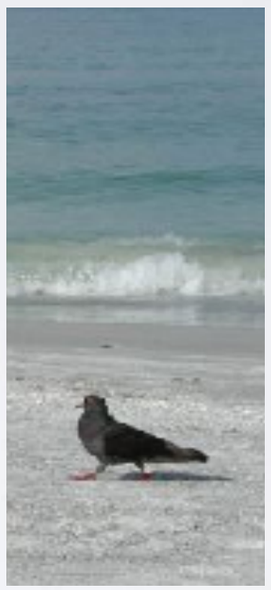
Image Resizing

Q: How can you resize an image w/o affecting proportions?

Image Resizing

- Preserve important elements
- Remove/reduce repetitive areas
  - water, sand, …

Image Resizing



Fail **Fail** **Fail** **Success**

Image Resizing

- To shrink image
  - remove unimportant pixels
- Quantify pixel importance
  - How much it varies from neighbors
  - Sum of differences in intensity with neighbors

Image Resizing

- Grayscale 3x3 image with the following pixel intensities
- Importance of the center pixel?

4	**6**	**5**
2	**5**	**7**
3	**2**	**6**

Image Resizing

- Pixel importance
  - Sum of differences in intensity with neighbors

Activity #1

1 min

Image Resizing

Activity #1

1 min

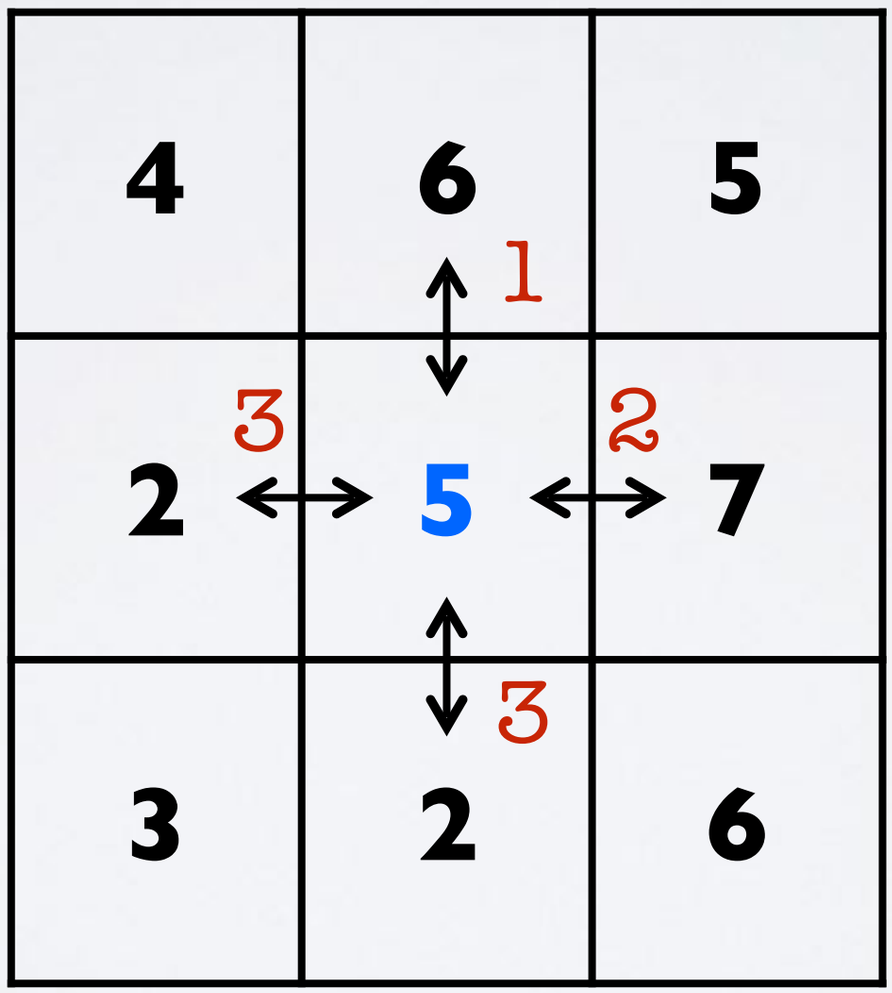
Image Resizing

Activity #1

0 min

Image Resizing

- Grayscale 3x3 image with the following pixel intensities
- Importance of the center pixel?



1+2+3+3 = 9

Image Resizing

- Quantify importance of every pixel
- Determine most and least important pixels

Low High

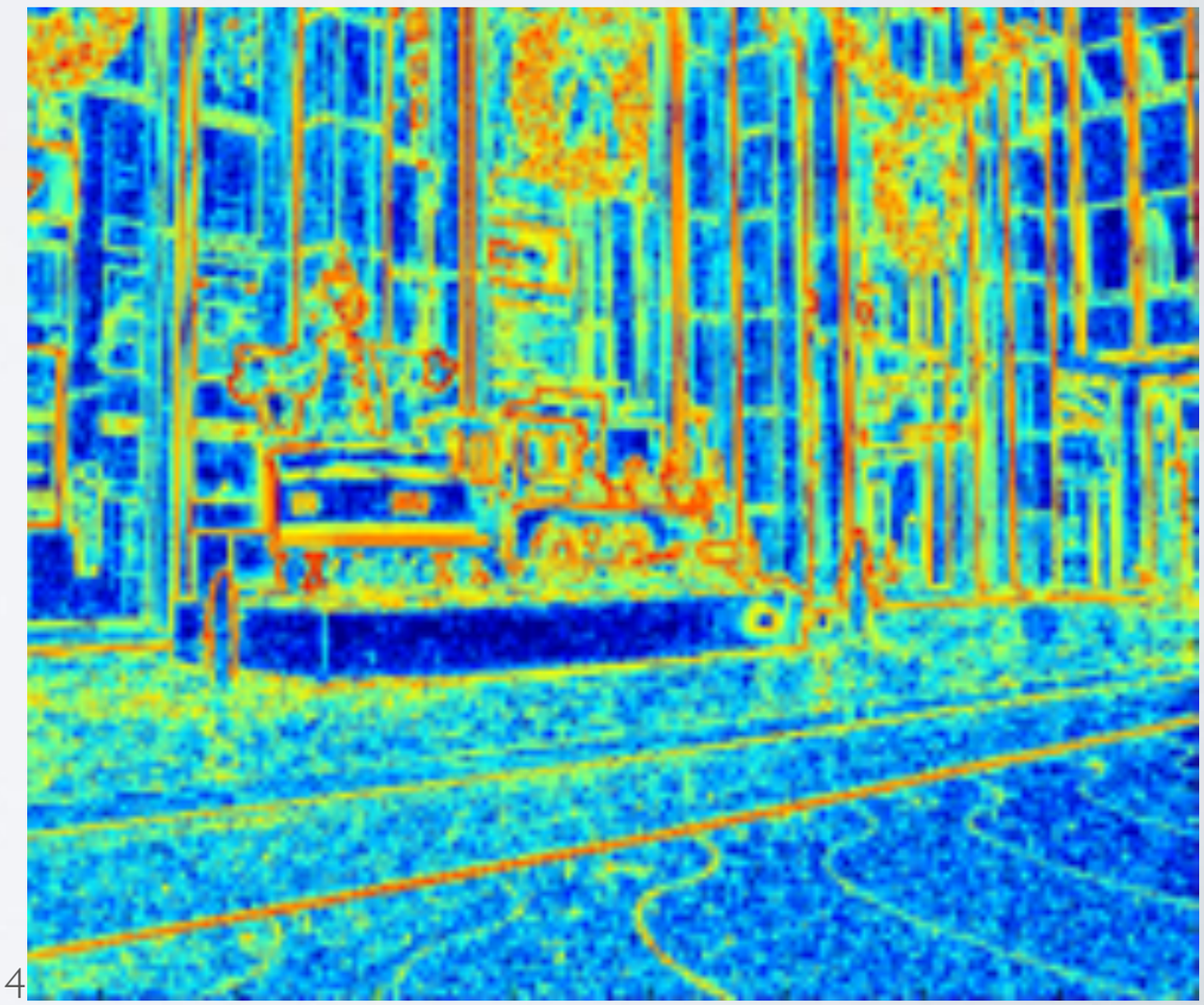


Image Resizing: Approach 1

- Remove all pixels with importance below some threshold
- Problem?
  - removing different amount from each row
  - causes jagged right side

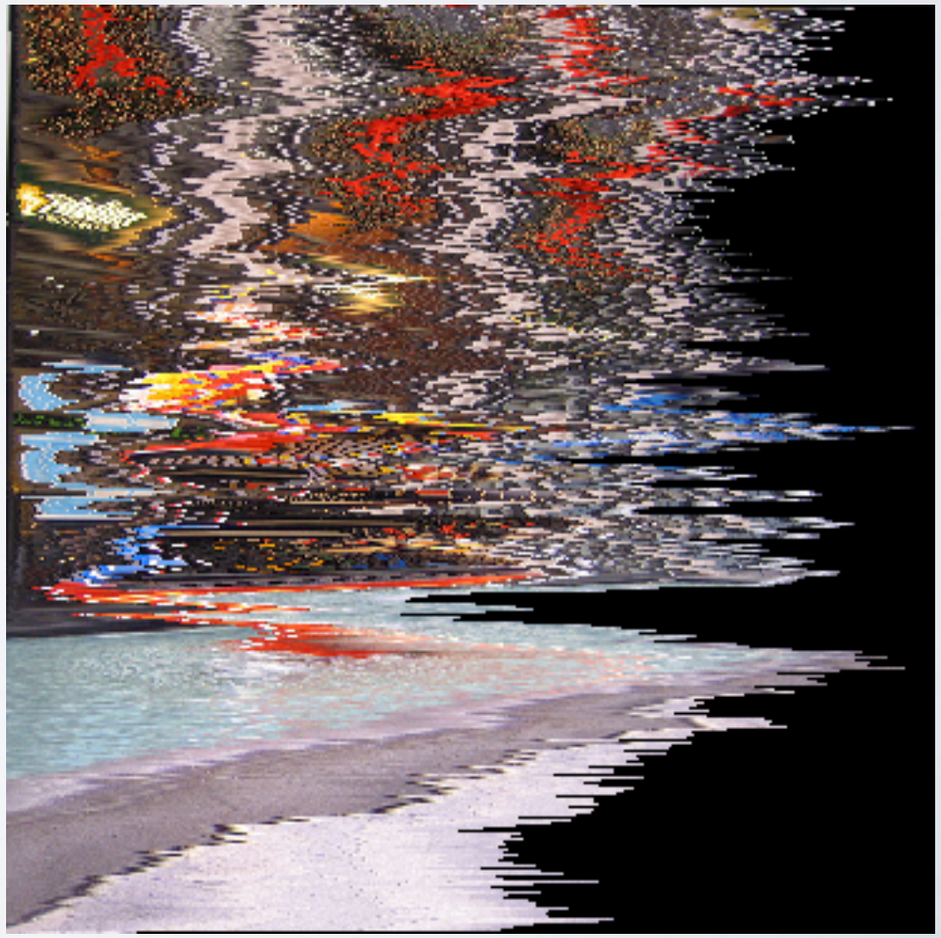


Image Resizing: Approach 2

- Remove **n** least important pixels in each row
- Still not great, too much shifting between adjacent rows

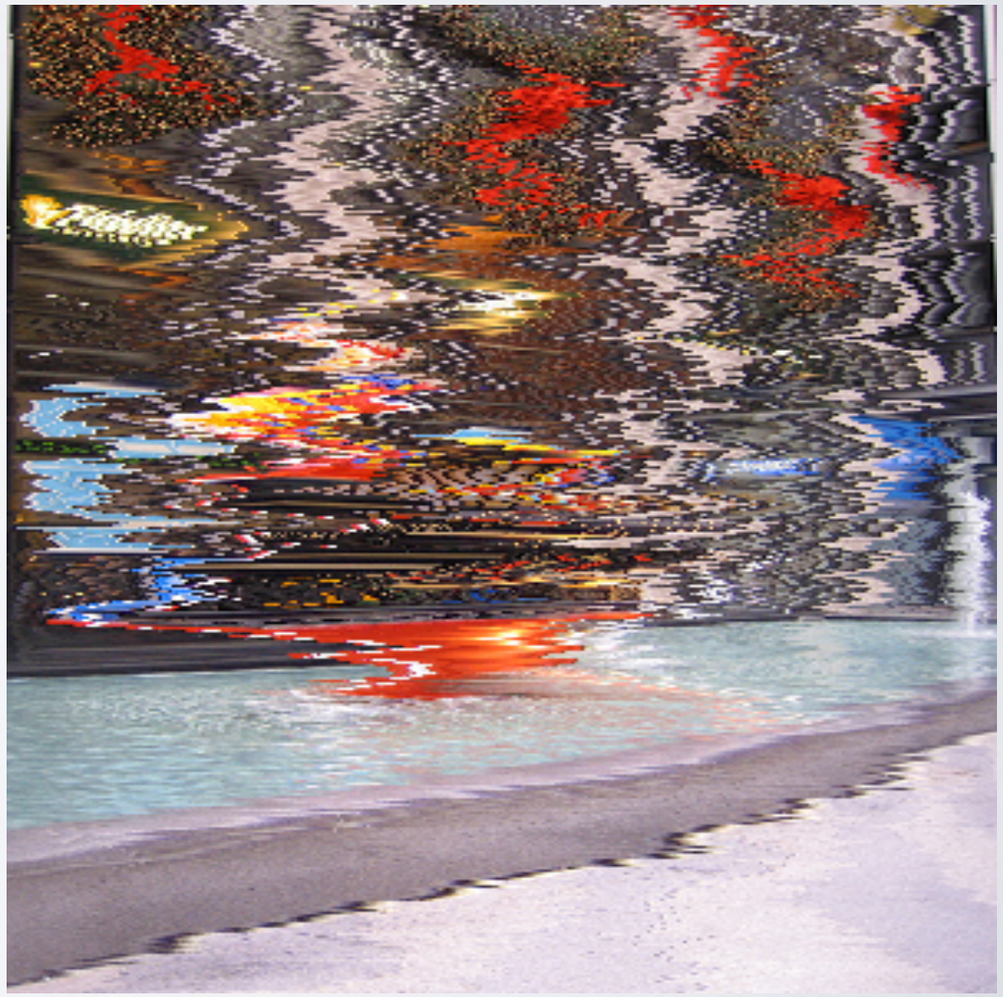
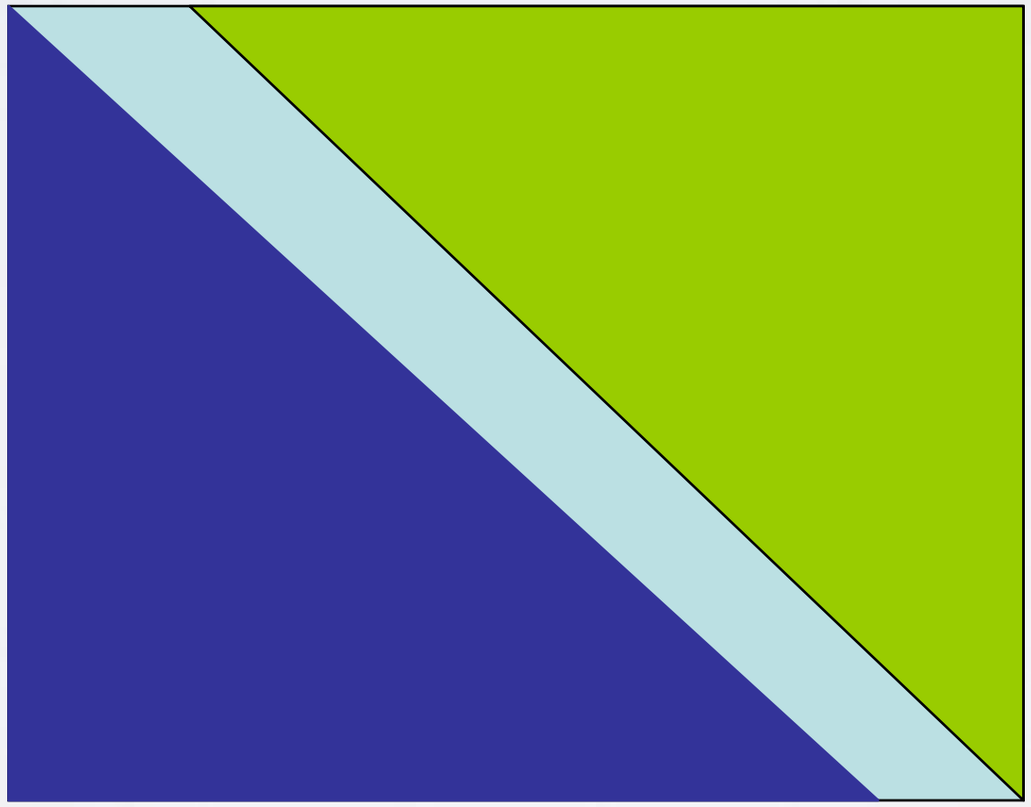


Image Resizing: Approach 3

- Remove column whose total importance is smallest, and repeat
- Much better! But not perfect…

Image Resizing

- Problem
  - removing entire column or entire row distorts image
- What pixels should we remove to resize this image?

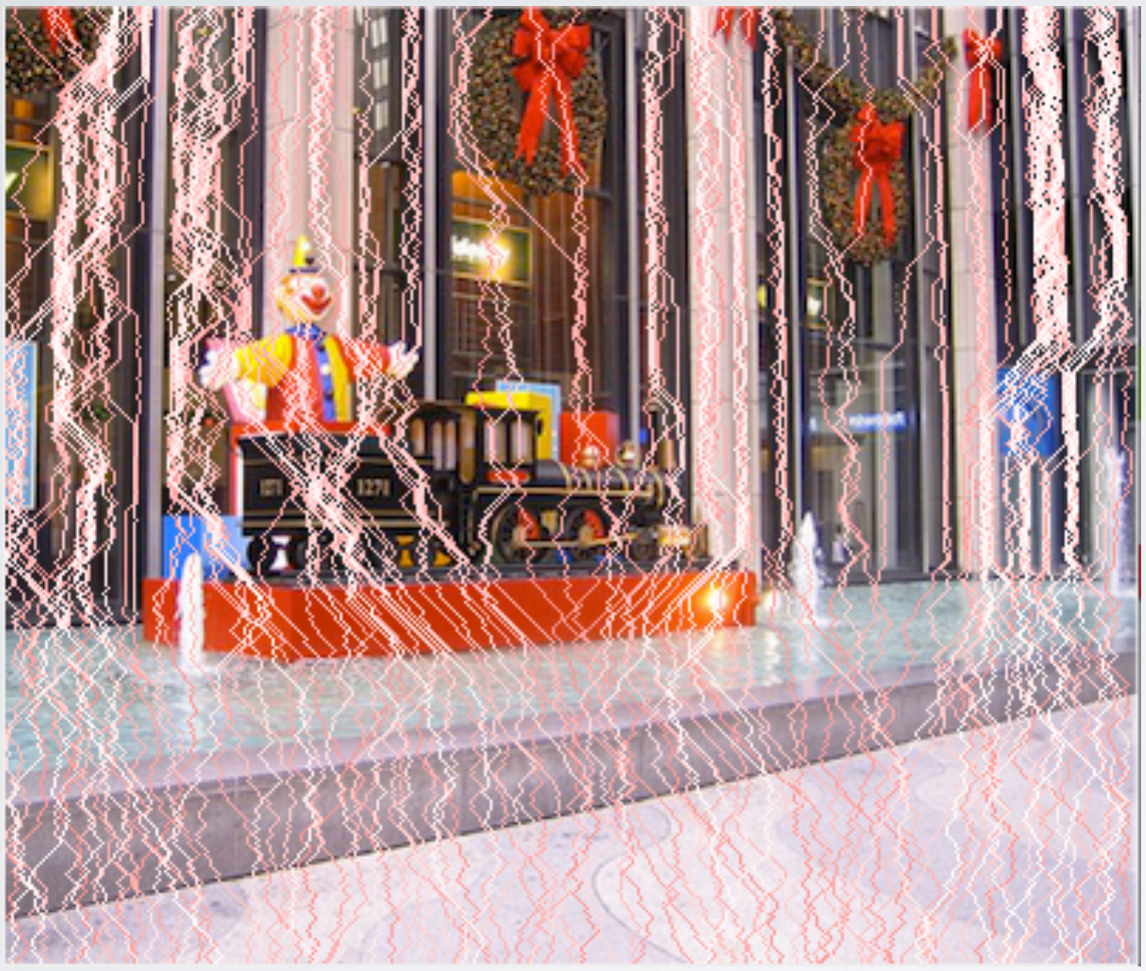


Seamcarve

- **Idea:** remove **seams** not columns
  - (vertical) seam is a path from top to bottom
  - that moves left or right by at most one pixel per row

=

Seamcarve



Near Perfection!

Object Removal via Seamcarve

- Mark object to remove as “unimportant”
  - artificially deflate the importance of its pixels
- Pixels will be removed by algorithm

Seamcarve

- Input
  - 2D array of importance values
- Output
  - Vertical seam with lowest importance

7x3 Importance Array

- Find and circle the best seam

Activity #2

1 min

7x3 Importance Array

Activity #2

1 min

7x3 Importance Array

Activity #2

0 min

7x3 Importance Array

9	3	8	15	1	11	7
6	13	9	5	10	4	14
9	6	7	9	14	7	11

7x7 Importance Array

- Find and circle the best seam

Activity #3

1 min

7x3 Importance Array

Activity #3

1 min

7x3 Importance Array

Activity #3

0 min

7x3 Importance Array

13	3	1	10	8	11	4
6	10	4	11	12	5	10
1	6	14	10	7	14	7
14	12	10	15	13	3	8
9	3	8	15	1	11	7
6	13	9	5	10	4	14
9	6	7	9	14	7	11

10x10 Importance Array

1	2	6	9	12	6	5	12	5	6
2	3	11	14	10	6	15	9	9	1
2	9	13	4	1	7	10	4	12	11
6	5	15	12	11	4	7	15	8	5
14	15	11	12	4	14	3	10	1	10
6	12	13	8	15	6	13	3	13	11
2	1	14	6	14	4	13	14	7	4
14	8	4	11	14	6	12	10	2	7
6	8	12	13	2	11	6	6	8	7
11	2	15	9	8	12	10	8	6	9

10x10 Importance Array

1	2	6	9	12	6	5	12	5	6
2	3	11	14	10	6	15	9	9	1
2	9	13	4	1	7	10	4	12	11
6	5	15	12	11	4	7	15	8	5
14	15	11	12	4	14	3	10	1	10
6	12	13	8	15	6	13	3	13	11
2	1	14	6	14	4	13	14	7	4
14	8	4	11	14	6	12	10	2	7
6	8	12	13	2	11	6	6	8	7
11	2	15	9	8	12	10	8	6	9

Seams

- Approximately $cx3^r$ seams in **cxr** image
- For **10x10**
  - 590,490 seams
- For **500x500**
  - $1.81801…x10^{241}$ seams (242 digits)
- Age of the Universe
  - $4.3x10^{17}$ seconds

The Seamcarve Algorithm

- Function **`find_least_important_seam(vals)`**
  - **input**: **`vals`** is a 2D array of importance values
  - **output**: sequence of column indices that represents a seam

```
[[ -  S  -  -  ],
 [  S  -  -  -  ],
                      ⟶   [1, 0, 1, 2]
 [  -  S  -  -  ],
 [  -  -  S  -  ]]
```

7x3 Importance Array

13	3	1	10	8	11	4
6	10	4	11	12	5	10
1	6	14	10	7	14	7
14	12	10	15	13	3	8
9	3	8	15	1	11	7
6	13	9	5	10	4	14
9	6	7	9	14	7	11

Seam = `[6,5,4,5,4,5,5]`

Data Structures Needed

- **`costs`**: 2D array filled in from bottom to top
  - **`costs[row][col]`** holds total importance of lowest cost seam starting from the bottom row and ending at **`costs[row][col]`**
- **`dirs`**: 2D array filled in at the same time as costs
  - **`dirs[row][col]`** holds the direction (-1, 0, or 1) of the previous pixel in the lowest cost seam ending at **`costs[row][col]`**

vals

3	6	8
5	7	2
4	9	3

costs

9	10	
4	9	3

dirs

0	1	
-	-	-

```
costs[row][col] = min(costs[row+1][col-1 to col+1])
                  + vals[row][col]
```

Finding Least Important Seam

- Once **`costs`** is filled in
  - cell in top row with minimum value is the first pixel in least important seam
- Starting from that pixel
  - follow directions in **`dirs`** to find least important seam
  - and build its column index representation

Seamcarve Pseudocode

```
function find_least_important_seam(vals):
    dirs = 2D array with same dimensions as vals
    costs = 2D array with same dimensions as vals
    costs[height-1] = vals[height-1] // initialize bottom row of costs

    for row from height-2 to 0:
        for col from 0 to width-1:
            costs[row][col] = vals[row][col] +
                              min(costs[row+1][col-1],
                                  costs[row+1][col],
                                  costs[row+1][col+1])
            dirs[row][col] = -1, 0, or 1 // depending on min

    // Find least important start pixel
    min_col = argmin(costs[0]) // Returns index of min in top row

    // Create vertical seam of size 'height' by tracing from top
    seam = []
    seam[0] = min_col
    for row from 0 to height-2:
        seam[row+1] = seam[row] + dirs[row][seam[row]]

    return seam
```

What's **`argmin`**?

- What does **`min`** do?
  - returns minimum output of a function
- What does **`argmin`** do?
  - given function **`f(x)`** returns x that minimizes **`f(x)`**
  - `f(x) = -1+x²`
    - `min f = -1`
    - **`argmin f = 0`** // value for which f is -1
- Array **`A = [5,4,1,3,9]`**
  - **`min(A) = 1`**
  - **`argmin(A) = 2`** // the index of the minimum value

Hand Simulate

```
   …
costs[height-1] = vals[height-1] // initialize bottom row of costs

 for row from height-2 to 0:
     for col from 0 to width-1:
         costs[row][col] = vals[row][col] +
                           min(costs[row+1][col-1],
                               costs[row+1][col],
                               costs[row+1][col+1])
         dirs[row][col] = -1, 0, or 1 // depending on min

 // Find least important start pixel
 min_col = argmin(costs[0]) // Returns index of min in top row

 // Create vertical seam of size ‘height’ by tracing from top
 seam = []
 seam[0] = min_col
 for row from 0 to height-2:
     seam[row+1] = seam[row] + dirs[row][seam[row]]

 return seam
```

Activity #4

3 min

Hand Simulate

```
   …
costs[height-1] = vals[height-1] // initialize bottom row of costs

 for row from height-2 to 0:
     for col from 0 to width-1:
         costs[row][col] = vals[row][col] +
                           min(costs[row+1][col-1],
                               costs[row+1][col],
                               costs[row+1][col+1])
         dirs[row][col] = -1, 0, or 1 // depending on min

 // Find least important start pixel
 min_col = argmin(costs[0]) // Returns index of min in top row

 // Create vertical seam of size ‘height’ by tracing from top
 seam = []
 seam[0] = min_col
 for row from 0 to height-2:
     seam[row+1] = seam[row] + dirs[row][seam[row]]

 return seam
```

Activity #4

2 min

Hand Simulate

```
   …
costs[height-1] = vals[height-1] // initialize bottom row of costs

 for row from height-2 to 0:
     for col from 0 to width-1:
         costs[row][col] = vals[row][col] +
                           min(costs[row+1][col-1],
                               costs[row+1][col],
                               costs[row+1][col+1])
         dirs[row][col] = -1, 0, or 1 // depending on min

 // Find least important start pixel
 min_col = argmin(costs[0]) // Returns index of min in top row

 // Create vertical seam of size ‘height’ by tracing from top
 seam = []
 seam[0] = min_col
 for row from 0 to height-2:
     seam[row+1] = seam[row] + dirs[row][seam[row]]

 return seam
```

Activity #4

1 min

Hand Simulate

```
   …
costs[height-1] = vals[height-1] // initialize bottom row of costs

 for row from height-2 to 0:
     for col from 0 to width-1:
         costs[row][col] = vals[row][col] +
                           min(costs[row+1][col-1],
                               costs[row+1][col],
                               costs[row+1][col+1])
         dirs[row][col] = -1, 0, or 1 // depending on min

 // Find least important start pixel
 min_col = argmin(costs[0]) // Returns index of min in top row

 // Create vertical seam of size ‘height’ by tracing from top
 seam = []
 seam[0] = min_col
 for row from 0 to height-2:
     seam[row+1] = seam[row] + dirs[row][seam[row]]

 return seam
```

Activity #4

0 min

Readings

- The original Seamcarve paper
  - http://www.eng.tau.ac.il/~avidan/papers/imretFinal.pdf
- Don't expect to understand it all but has nice examples and is a worthwhile read

Announcements

- Section starts on Monday!
  - Sign up
- HW1 is out tomorrow
- Seamcarve is out
- Python lab next week