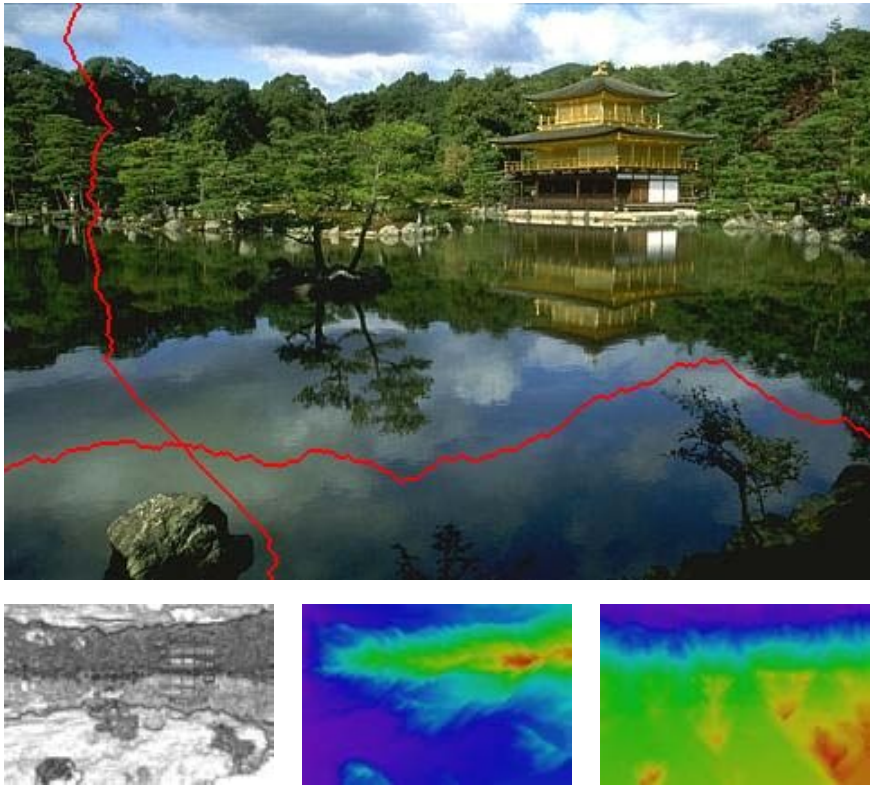
Seam Carving for Content-Aware Image Resizing

DSP Lab 2021

Goal

- Our approach to content-aware resizing is to remove pixels in a judicious manner
- The question is how to choose the pixels to be removed?
- Our goal is to remove unnoticeable pixels that blend with their surroundings
- This leads to the following simple energy function



Standard Scaling

- Content-aware resizing

- Standard scaling

Energy function

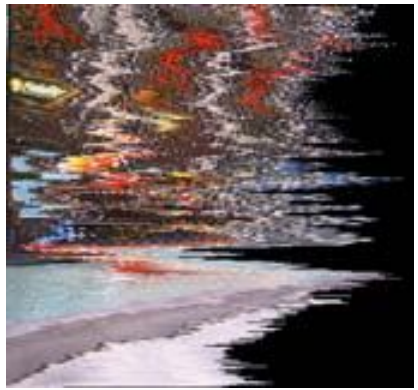
$$e_1(\mathbf{I}) = |\frac{\partial}{\partial x}\mathbf{I}| + |\frac{\partial}{\partial y}\mathbf{I}|$$

Crop

Column

Seam

Pixel in Row



Pixel in Image

Seam

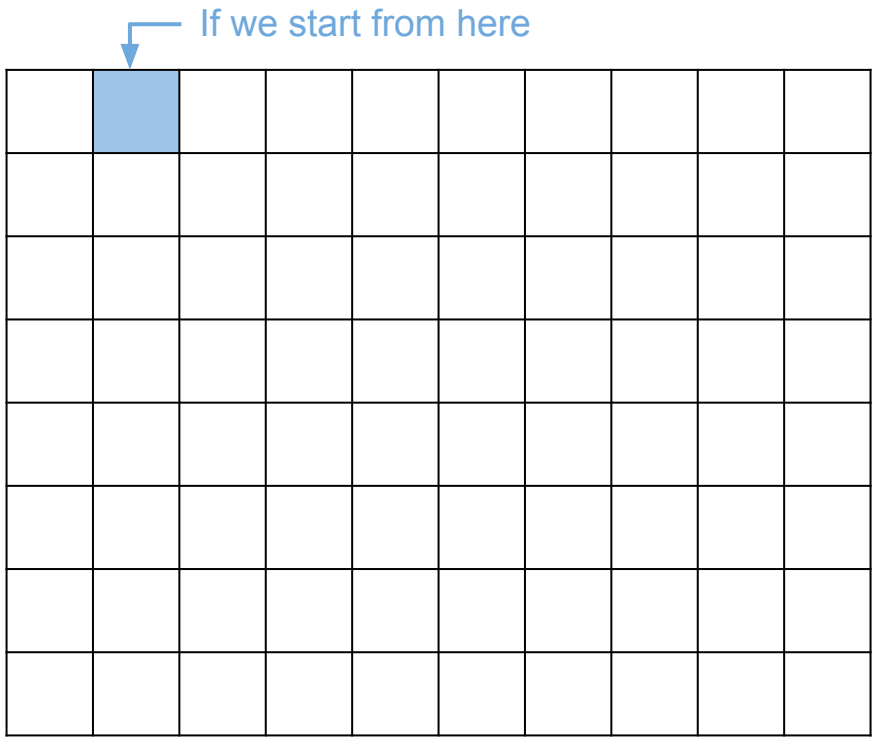
Let I be an n × m image and define a **vertical seam** to be:

$$s^x = \{s_i^x\}_{i=1}^n = \{(x(i), i)\}_{i=1}^n, \ \ s.t. \ \forall i, |x(i) - x(i-1)| \leq 1$$

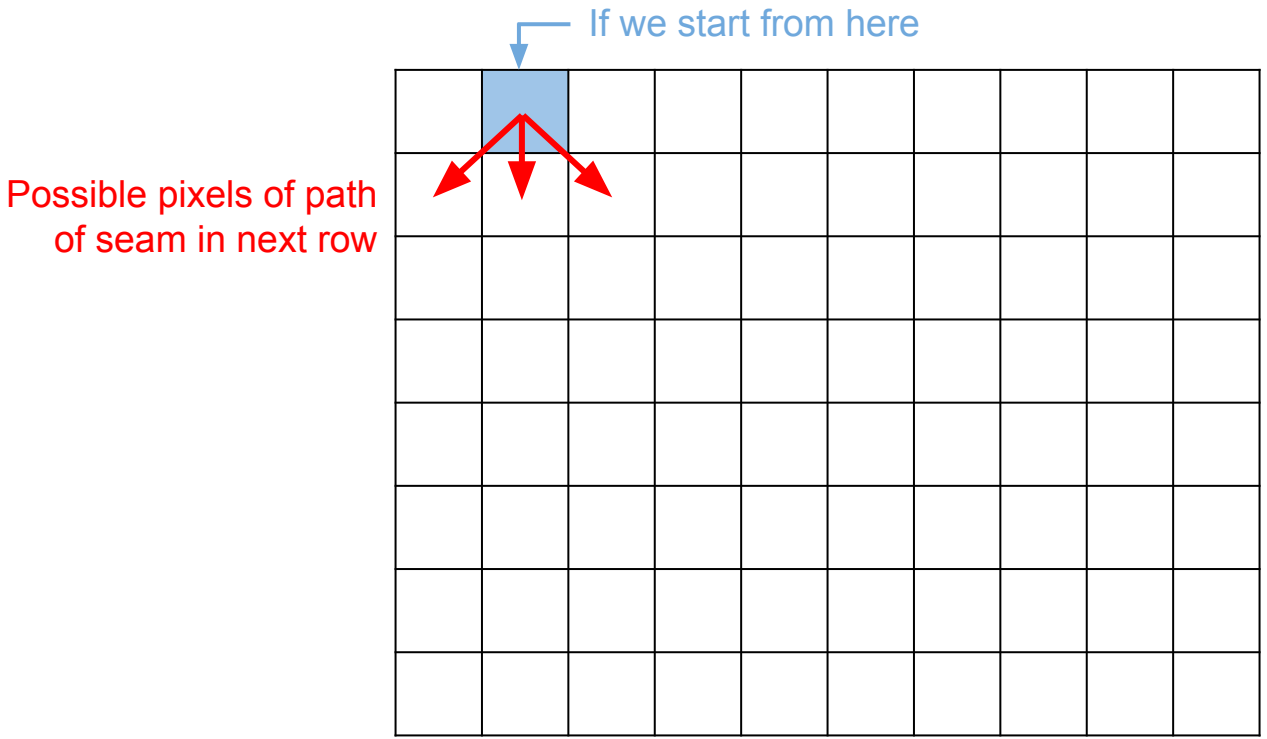
where i is the row index, x is a mapping x: [1, ... , n] → [1, ... , m]

only one pixel in each row of the image

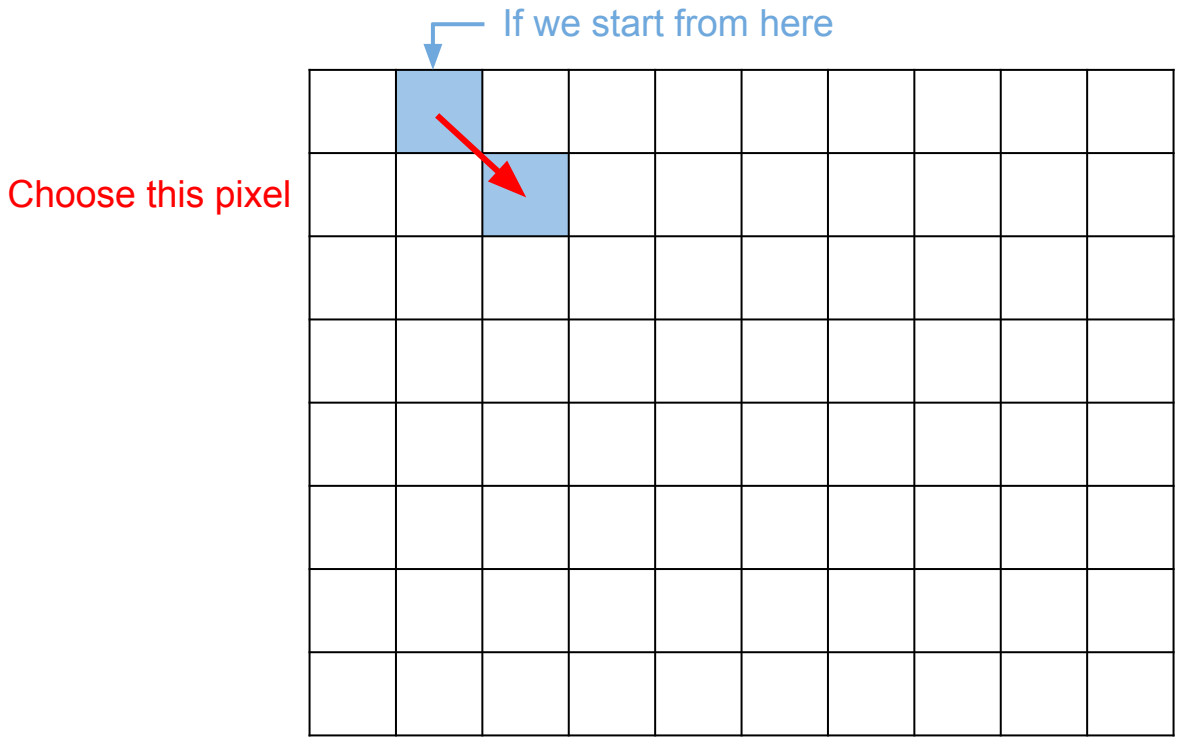
Seam



Seam

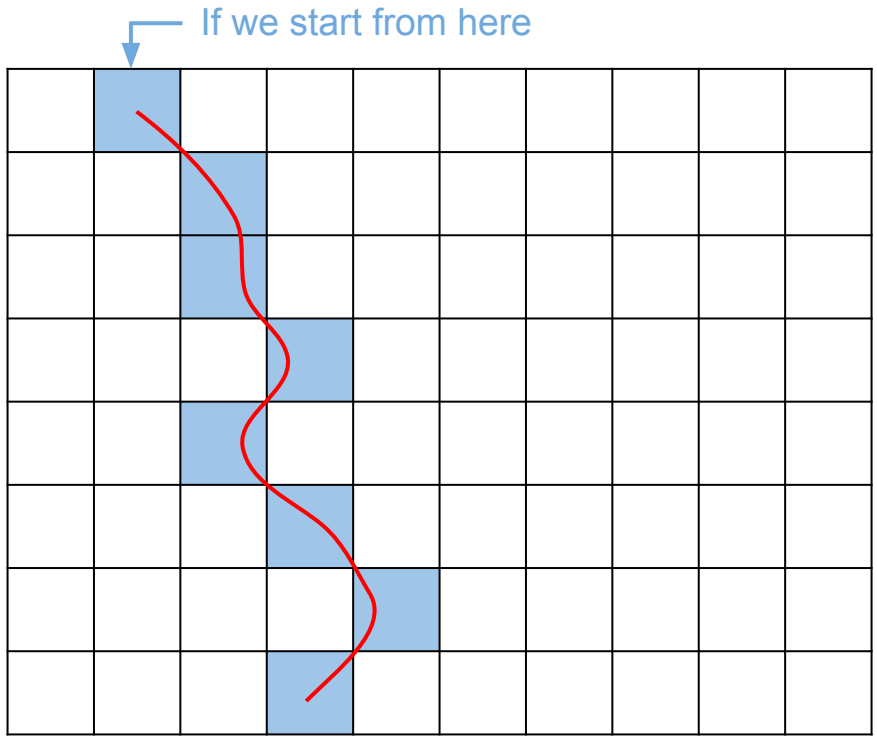

If we start from here
Possible pixels of path
of seam in next row

Seam



Seam

Repeat & Get one possible seam



Optimal Seam

We are looking for a seam with the minimum energy among all seams:

$$s^* = \min_s E(s) = \min_s \sum_{i=1}^{n} e(I(S_i))$$

1. Find M – minimum energy for all possible seams for each (i, j)
   - Fill energy in the first row.
   - Calculate M for all rows starting from second as below

$$M[i,j] = e[i,j] + \min\left(M[i-1,j-1], M[i-1,j], M[i-1,j+1]\right)$$

2. Find the minimum value in the last row of M and traverse back choosing pixels with minimum energy

Optimal Seam

Energy map of image

2	4	3	5	7	6	8	1	3	2
4	1	3	6	8	1	3	4	8	2
1	2	6	8	4	4	2	5	1	9
7	1	7	5	2	2	8	3	7	2
3	2	9	5	3	1	7	4	4	3
9	6	5	3	6	1	3	4	9	8
8	9	3	7	4	1	2	4	6	8
8	8	3	6	7	4	1	3	9	6

M - minimum energy for all possible seams

2	4	3	5	7	6	8	1	3	2

Fill in the energy in first row

Optimal Seam

Energy map of image

2	4	3	5	7	6	8	1	3	2
4	1	3	6	8	1	3	4	8	2
1	2	6	8	4	4	2	5	1	9
7	1	7	5	2	2	8	3	7	2
3	2	9	5	3	1	7	4	4	3
9	6	5	3	6	1	3	4	9	8
8	9	3	7	4	1	2	4	6	8
8	8	3	6	7	4	1	3	9	6

M - minimum energy for all possible seams

	2	4	3	5	7	6	8	1	3	2
6									

Add on the minimum energy with possible pixel of seam

Optimal Seam

Energy map of image

2	4	3	5	7	6	8	1	3	2
4	1	3	6	8	1	3	4	8	2
1	2	6	8	4	4	2	5	1	9
7	1	7	5	2	2	8	3	7	2
3	2	9	5	3	1	7	4	4	3
9	6	5	3	6	1	3	4	9	8
8	9	3	7	4	1	2	4	6	8
8	8	3	6	7	4	1	3	9	6

M - minimum energy for all possible seams

2	4	3	5	7	6	8	1	3	2
6	3								

Add on the minimum energy with possible pixel of seam

Optimal Seam

Energy map of image

2	4	3	5	7	6	8	1	3	2
4	1	3	6	8	1	3	4	8	2
1	2	6	8	4	4	2	5	1	9
7	1	7	5	2	2	8	3	7	2
3	2	9	5	3	1	7	4	4	3
9	6	5	3	6	1	3	4	9	8
8	9	3	7	4	1	2	4	6	8
8	8	3	6	7	4	1	3	9	6

M - minimum energy for all possible seams

2	4	3	5	7	6	8	1	3	2
6	3	6	9	13	7	4	5	9	4
4	5	9	14	11	8	6	9	5	13
11	5	12	14	10	8	14	8	12	7
8	7	14	15	11	9	15	12	11	10
16	13	12	14	15	10	12	15	19	18
21	21	15	19	14	11	12	16	21	16
29	23	18	20	18	15	12	15	25	27

Optimal Seam

Seam Index Array

0
0
0
0
0
0
0
0

M - minimum energy for all possible seams

2	4	3	5	7	6	8	1	3	2
6	3	6	9	13	7	4	5	9	4
4	5	9	14	11	8	6	9	5	13
11	5	12	14	10	8	14	8	12	7
8	7	14	15	11	9	15	12	11	10
16	13	12	14	15	10	12	15	19	18
21	21	15	19	14	11	12	16	21	16
29	23	18	20	18	15	12	15	25	27

Find the minimum value in the last row and traverse back by choosing pixels with minimum energy

Optimal Seam

Seam Index Array

0
0
0
0
0
0
0
7

M - minimum energy for all possible seams

2	4	3	5	7	6	8	1	3	2
6	3	6	9	13	7	4	5	9	4
4	5	9	14	11	8	6	9	5	13
11	5	12	14	10	8	14	8	12	7
8	7	14	15	11	9	15	12	11	10
16	13	12	14	15	10	12	15	19	18
21	21	15	19	14	11	12	16	21	16
29	23	18	20	18	15	12	15	25	27

Traverse back and update the seam index array

Optimal Seam

Seam Index Array

0
0
0
0
0
0
6
7

M - minimum energy for all possible seams

2	4	3	5	7	6	8	1	3	2
6	3	6	9	13	7	4	5	9	4
4	5	9	14	11	8	6	9	5	13
11	5	12	14	10	8	14	8	12	7
8	7	14	15	11	9	15	12	11	10
16	13	12	14	15	10	12	15	19	18
21	21	15	19	14	11	12	16	21	16
29	23	18	20	18	15	12	15	25	27

Traverse back and update the seam index array

Optimal Seam

Seam Index Array

8
7
7
6
6
6
6
7

Use the seam index array to delete the seam from the original image

M - minimum energy for all possible seams

2	4	3	5	7	6	8	1	3	2
6	3	6	9	13	7	4	5	9	4
4	5	9	14	11	8	6	9	5	13
11	5	12	14	10	8	14	8	12	7
8	7	14	15	11	9	15	12	11	10
16	13	12	14	15	10	12	15	19	18
21	21	15	19	14	11	12	16	21	16
29	23	18	20	18	15	12	15	25	27

Optimal seam with minimum energy

Seam Insertion - Seam Carving on Duplicated Image

Seam Index Array

1	0	0
2	0	0
1	0	0
2	0	0
s_1	s_2	s_3

M - minimum energy for all possible seams

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

Calculate the energy map, find the optimal seam, and remove the optimal seam

Seam Insertion - Seam Carving on Duplicated Image

Seam Index Array

s_1	s_2	s_3
1	9	0
2	9	0
1	8	0
2	9	0

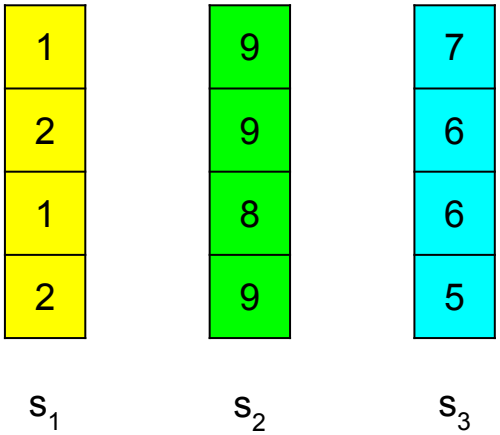
M - minimum energy for all possible seams

3	3	5	7	6	8	1	3	2
7	6	9	13	7	4	5	9	4
7	12	14	11	8	6	9	5	13
10	14	16	10	8	14	8	12	7

Recalculate the energy map, find the optimal seam, and remove the optimal seam

Seam Insertion - Seam Carving on Duplicated Image

Seam Index Array



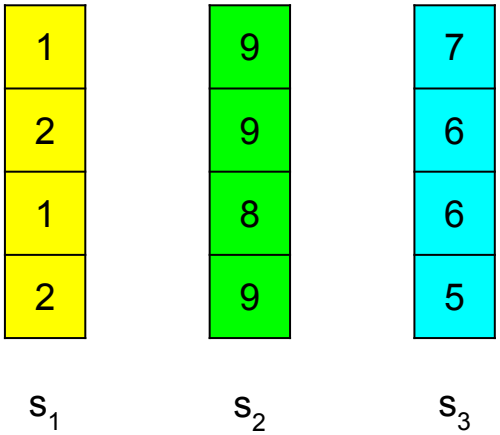
M - minimum energy for all possible seams

3	3	5	7	6	8	**1**	4
7	6	9	13	7	**4**	5	3
7	12	14	11	8	**6**	8	6
10	14	16	10	**8**	14	9	10

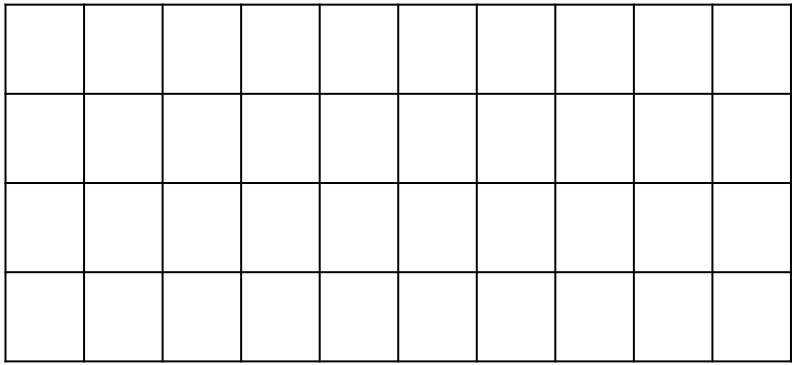
Recalculate the energy map, find the optimal seam, and remove the optimal seam

Seam Insertion

Seam Index Array

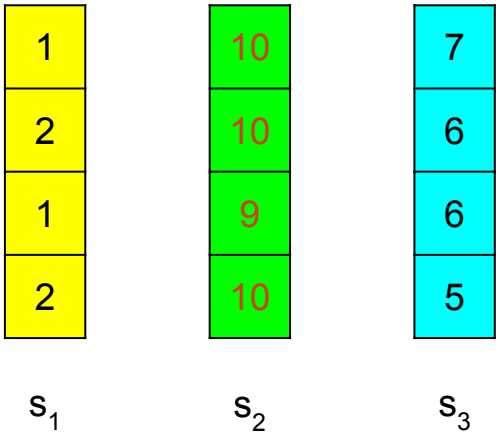


Image

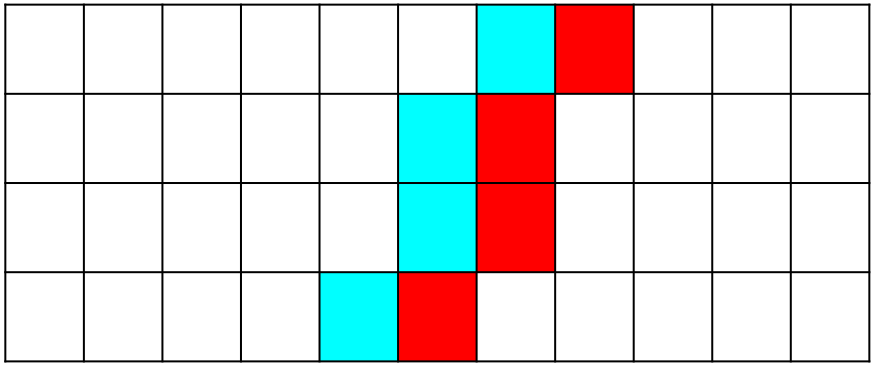


Seam Insertion - Insert beside s_3 on Original Image

Seam Index Array



Image



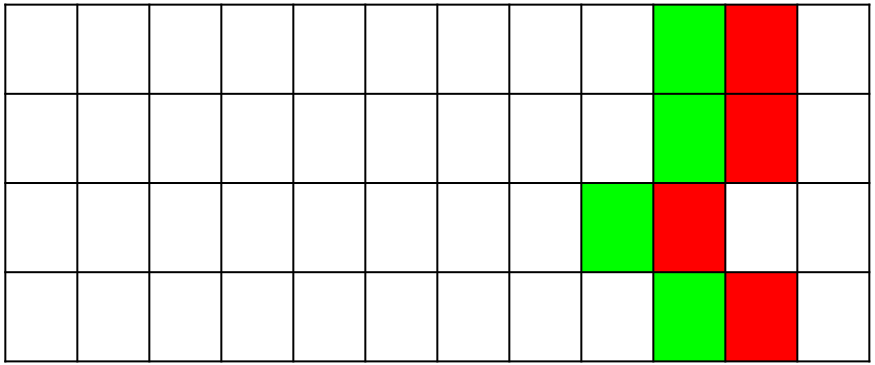
Insert beside s_3 and update affected seam index

Seam Insertion - Insert beside s_2 on Original Image

Seam Index Array

s_1	s_2	s_3
1	10	7
2	10	6
1	9	6
2	10	5

Image



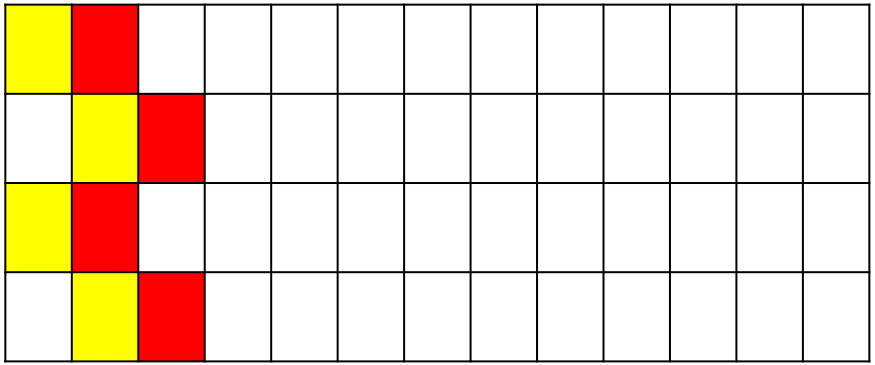
Insert beside s_2 and update affected seam index

Seam Insertion - Insert beside s_1 on Original Image

Seam Index Array

s_1	s_2	s_3
1	10	7
2	10	6
1	9	6
2	10	5

Image



Insert beside s_1 and update affected seam index

Implementation

- Calculate gradient of pixel in energyRGB.m
- Find optimal seam in findOptSeam.m
- Reduce image by seam index array in reduceImageByIndexArray.m and seamCarvingReduce.m
- Enlarge image by seam index array in enlargeImageByIndexArray.m and seamCarvingInsert.m