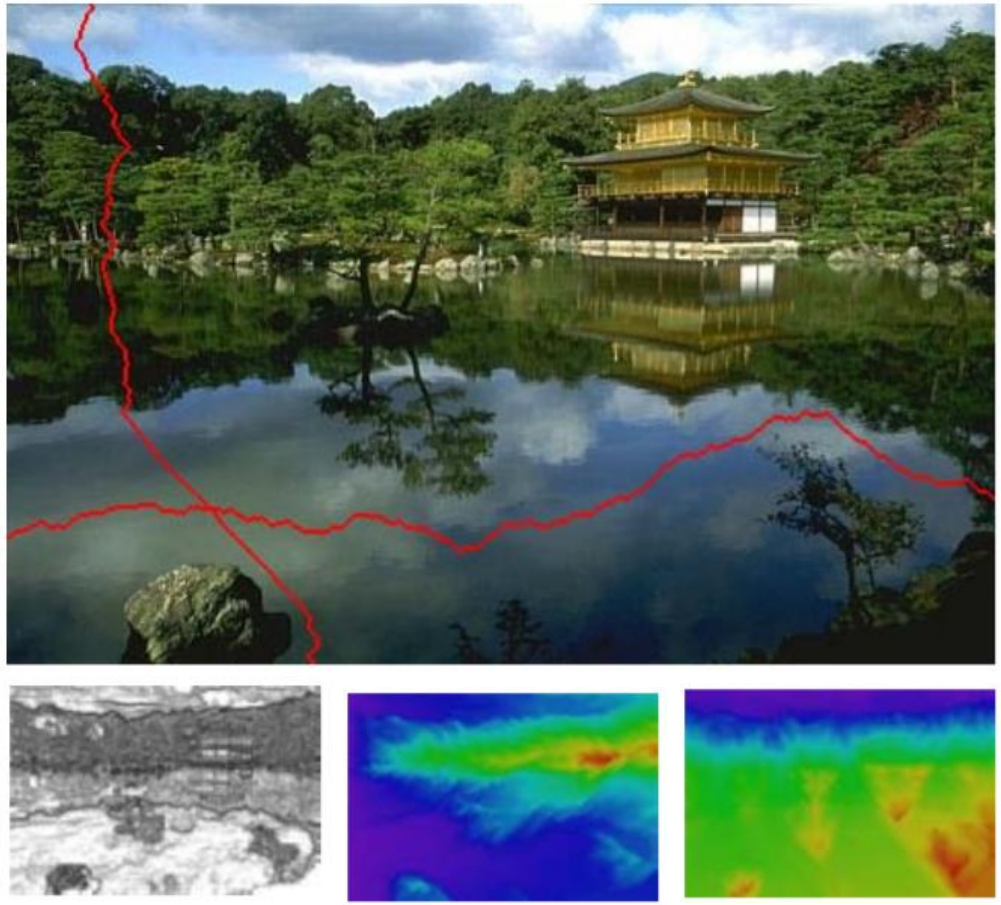
HW3: Seam Carving for Content-Aware Image Resizing

- Our approach to content-aware resizing is to remove pixels in a judicious manner
- The question is how to chose 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



HW3: Seam Carving for Content-Aware Image Resizing

Content-aware resizing

Standard scaling

Energy function

- Gradient of pixel

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

(b) Crop (c) Column (d) Seam (e) Pixel (f) Optimal

Seam

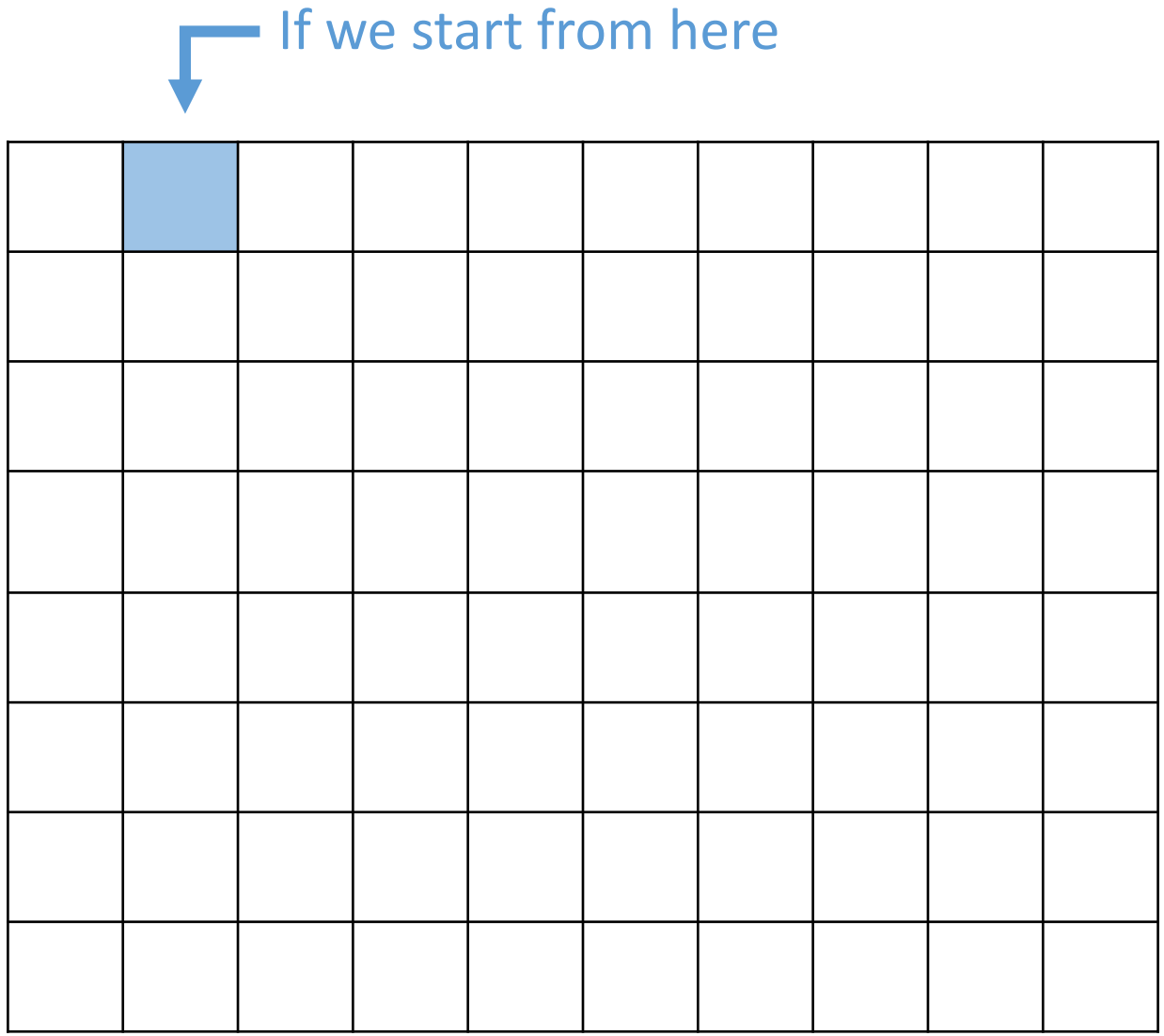
- Let I be an $n \times m$ image and define a ***vertical seam*** to be: $\mathbf{s}^{\mathbf{x}} = \{s_i^x\}_{i=1}^n = \{(x(i), i)\}_{i=1}^n$, s.t. $\forall i, |x(i) - x(i-1)| \leq 1$

  where i is the row index,

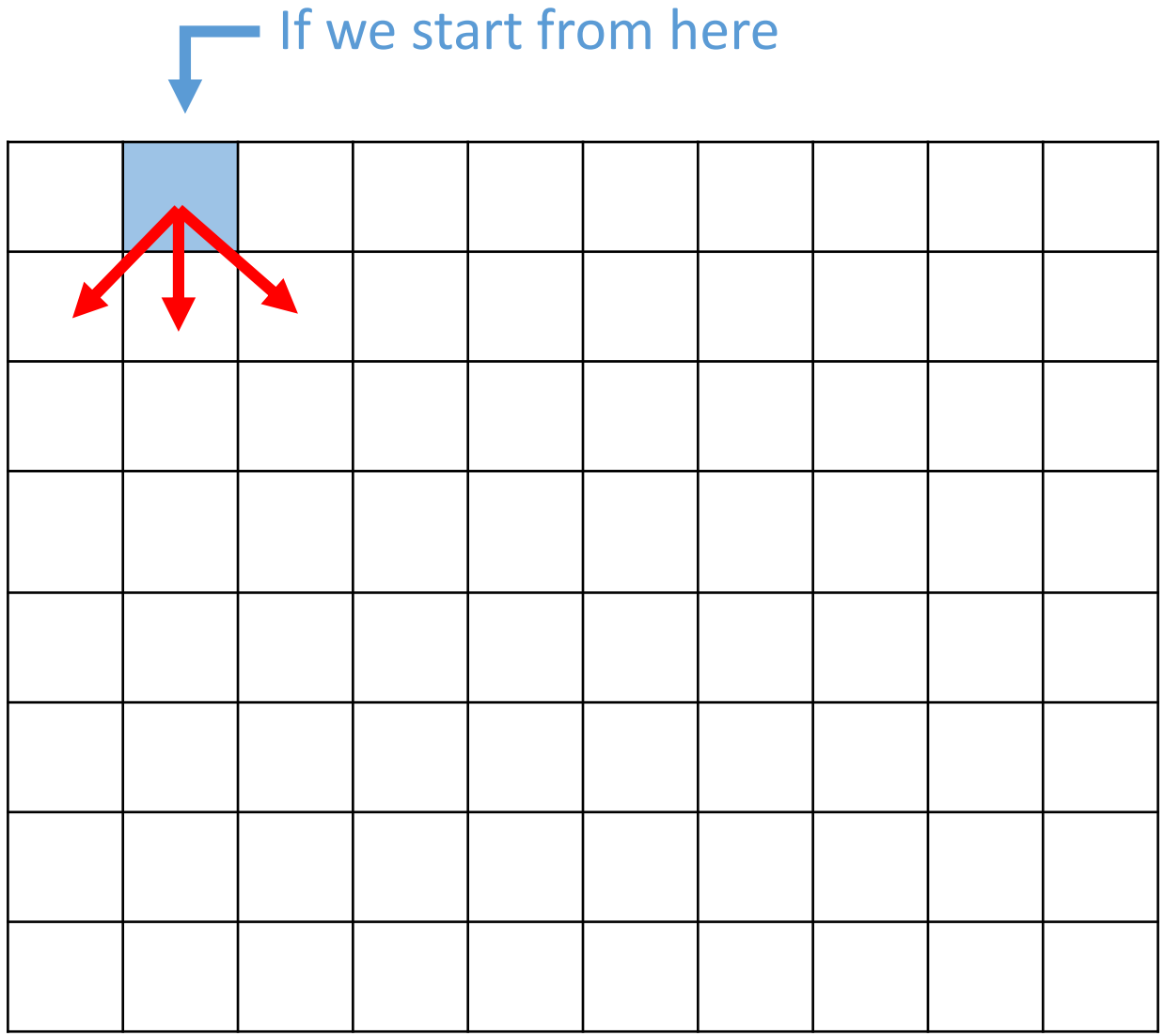
  x is a mapping x: $[1, \ldots, n] \rightarrow [1, \ldots, m]$

- only one pixel in each row of the image

Seam

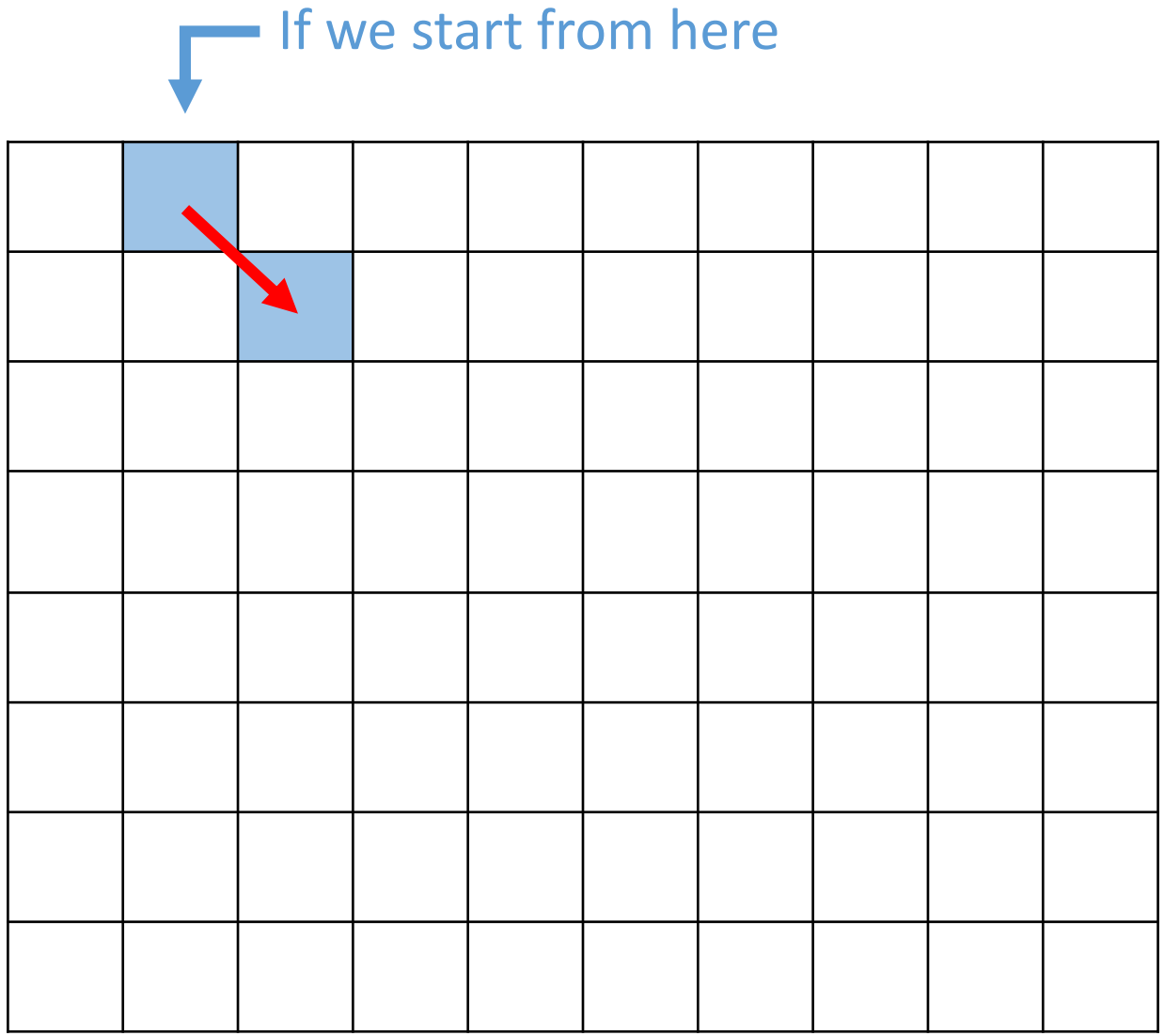


Seam

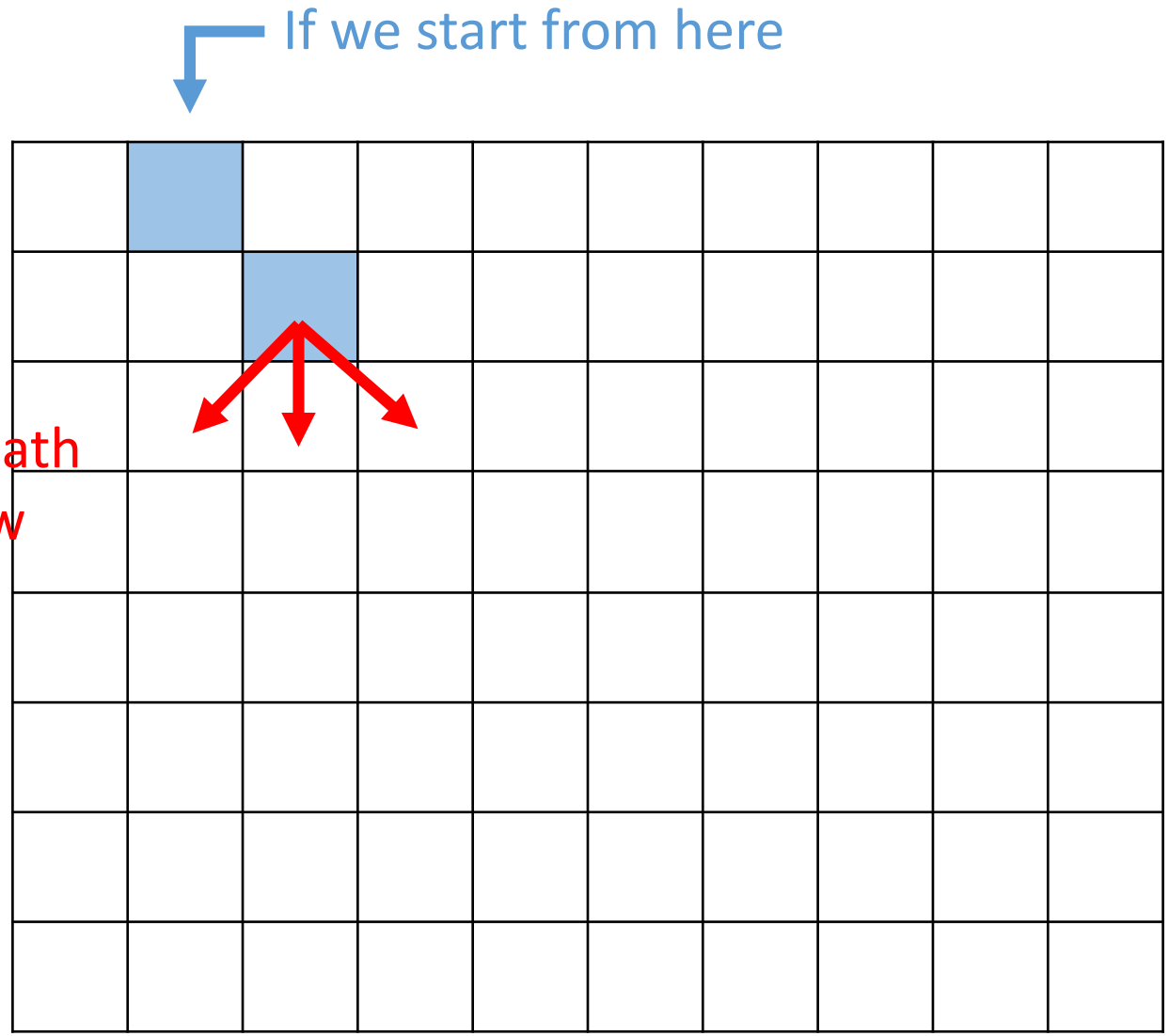


Possible pixels of path of seam in next row

Seam



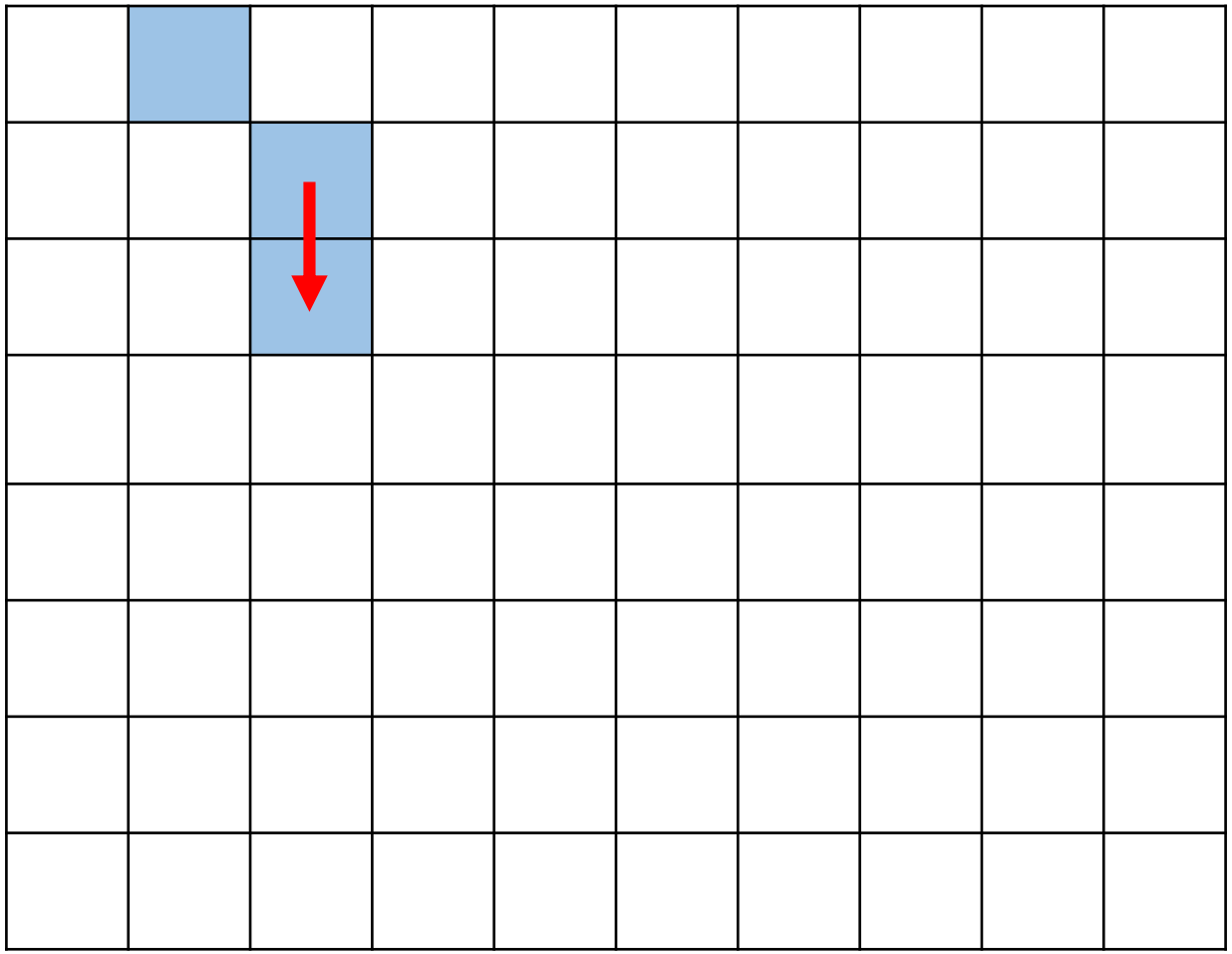
Seam


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

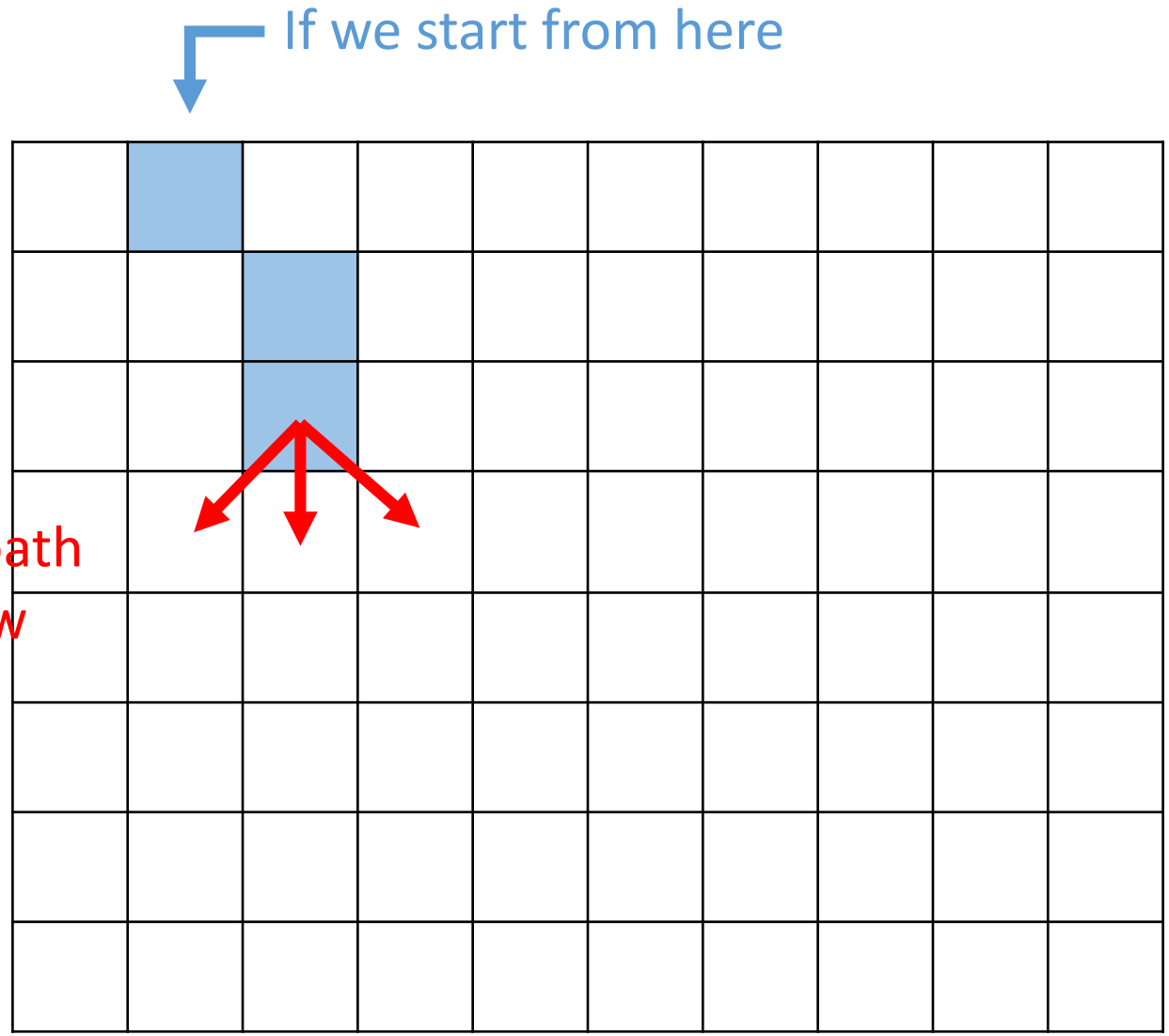
Seam

If we start from here

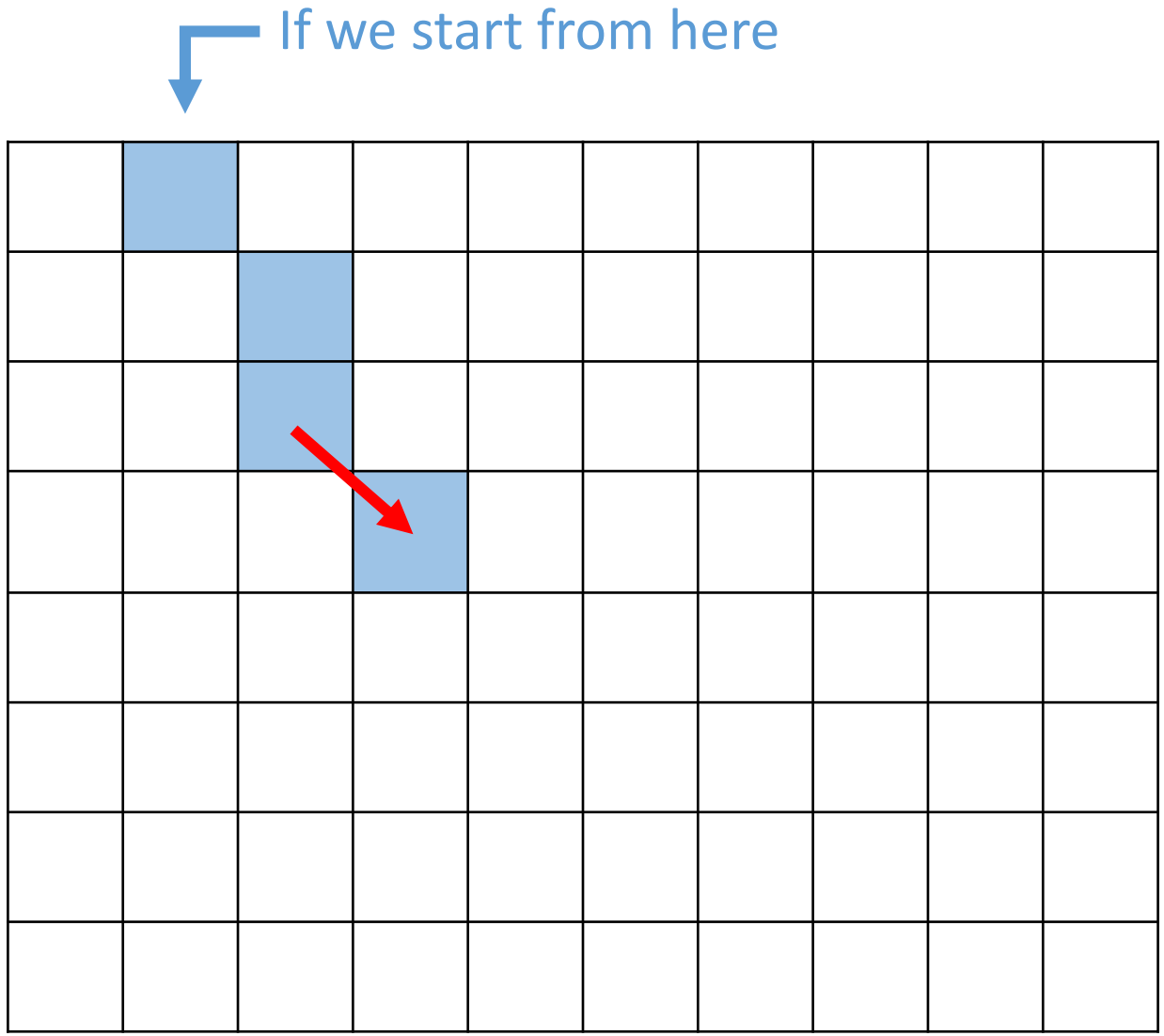
Choose this pixel



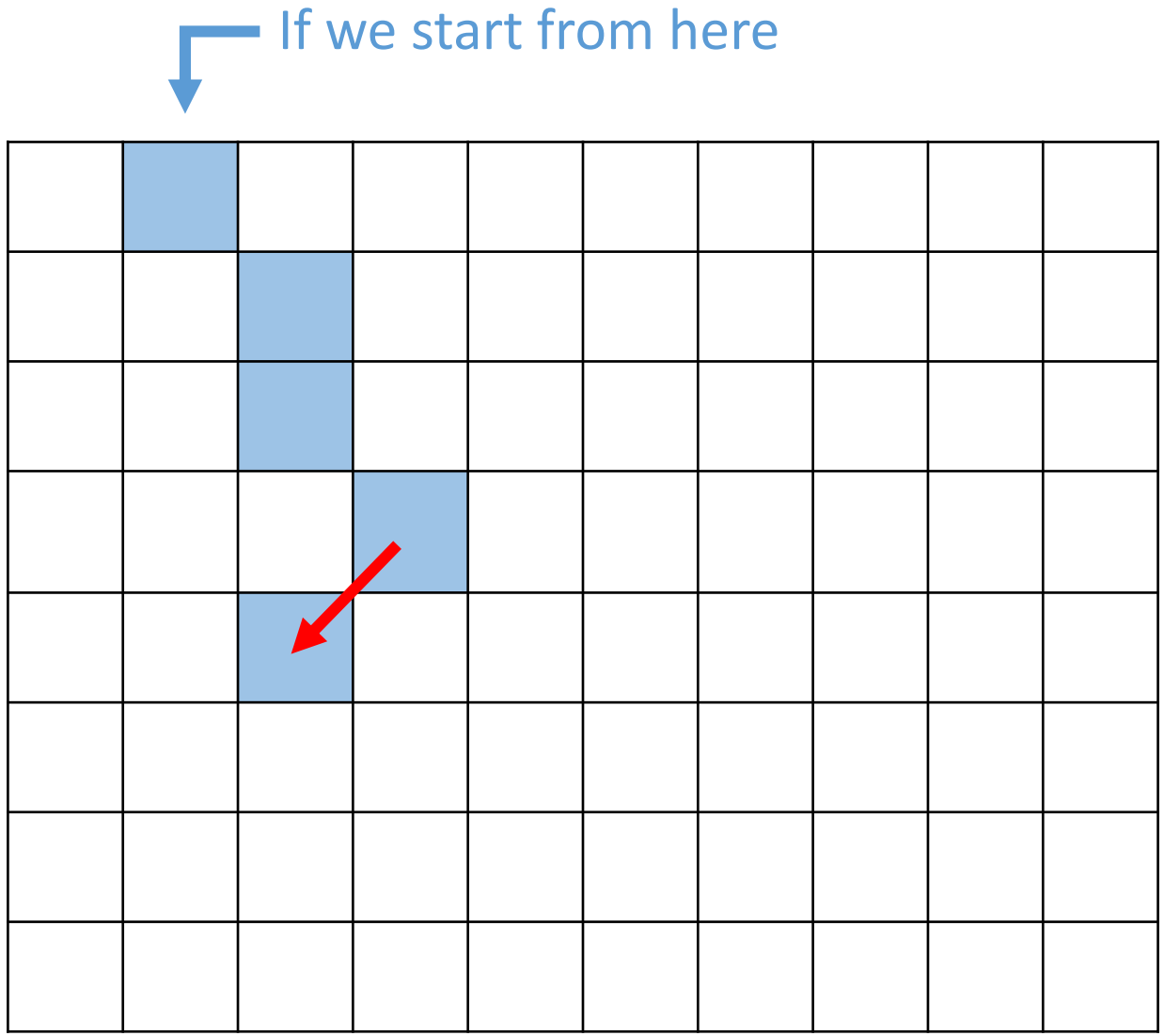
Seam


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

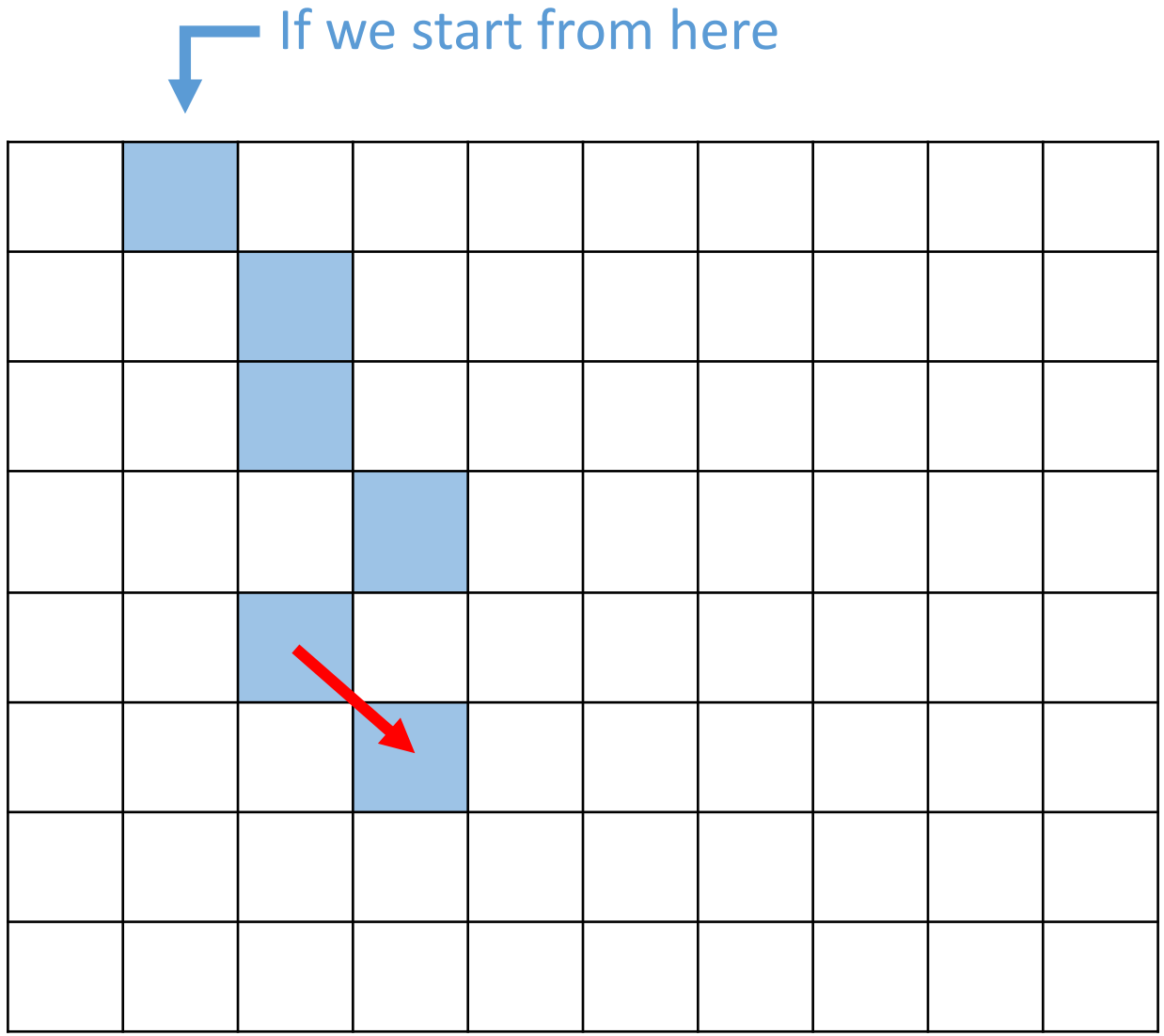
Seam



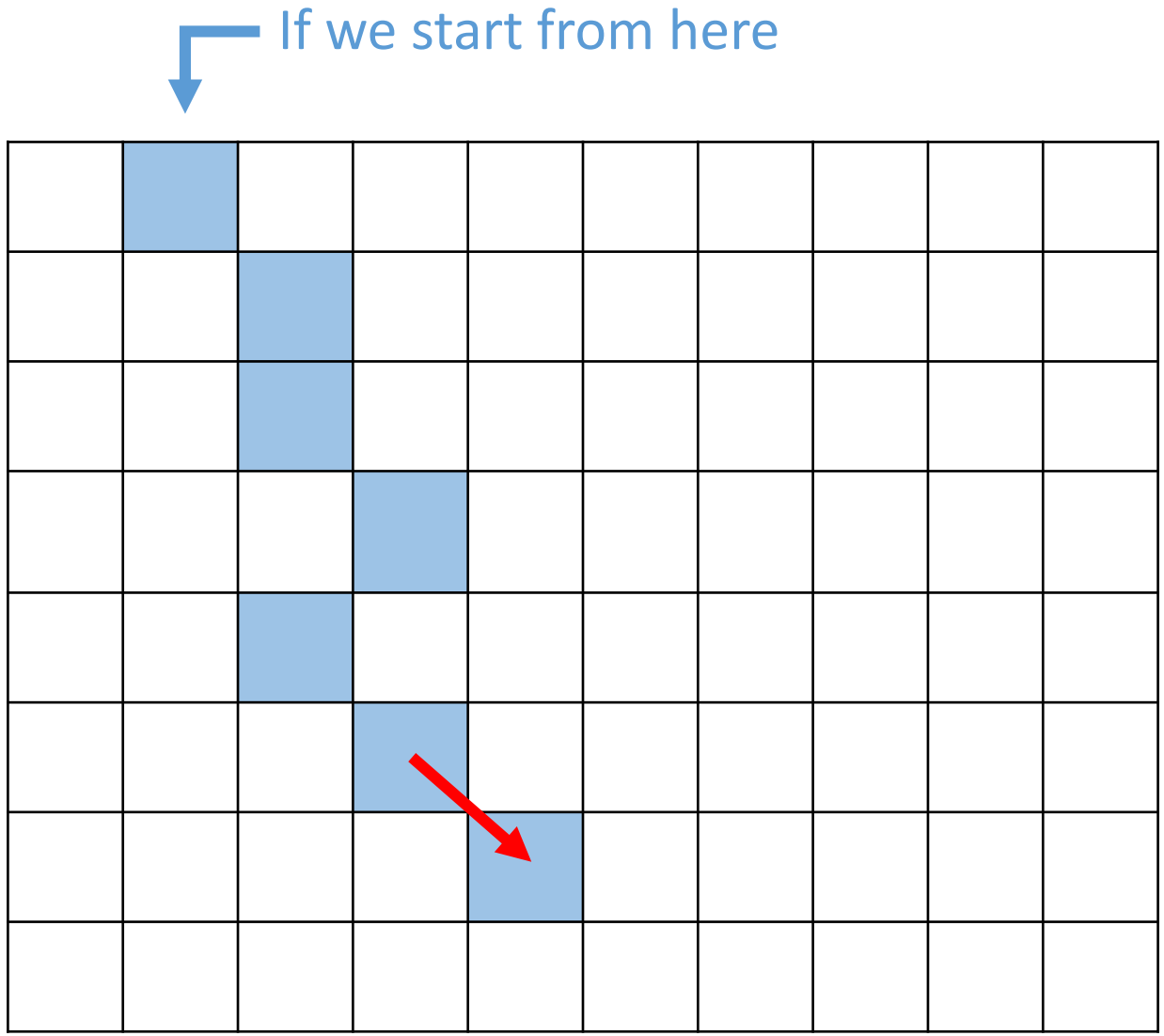
Seam



Seam

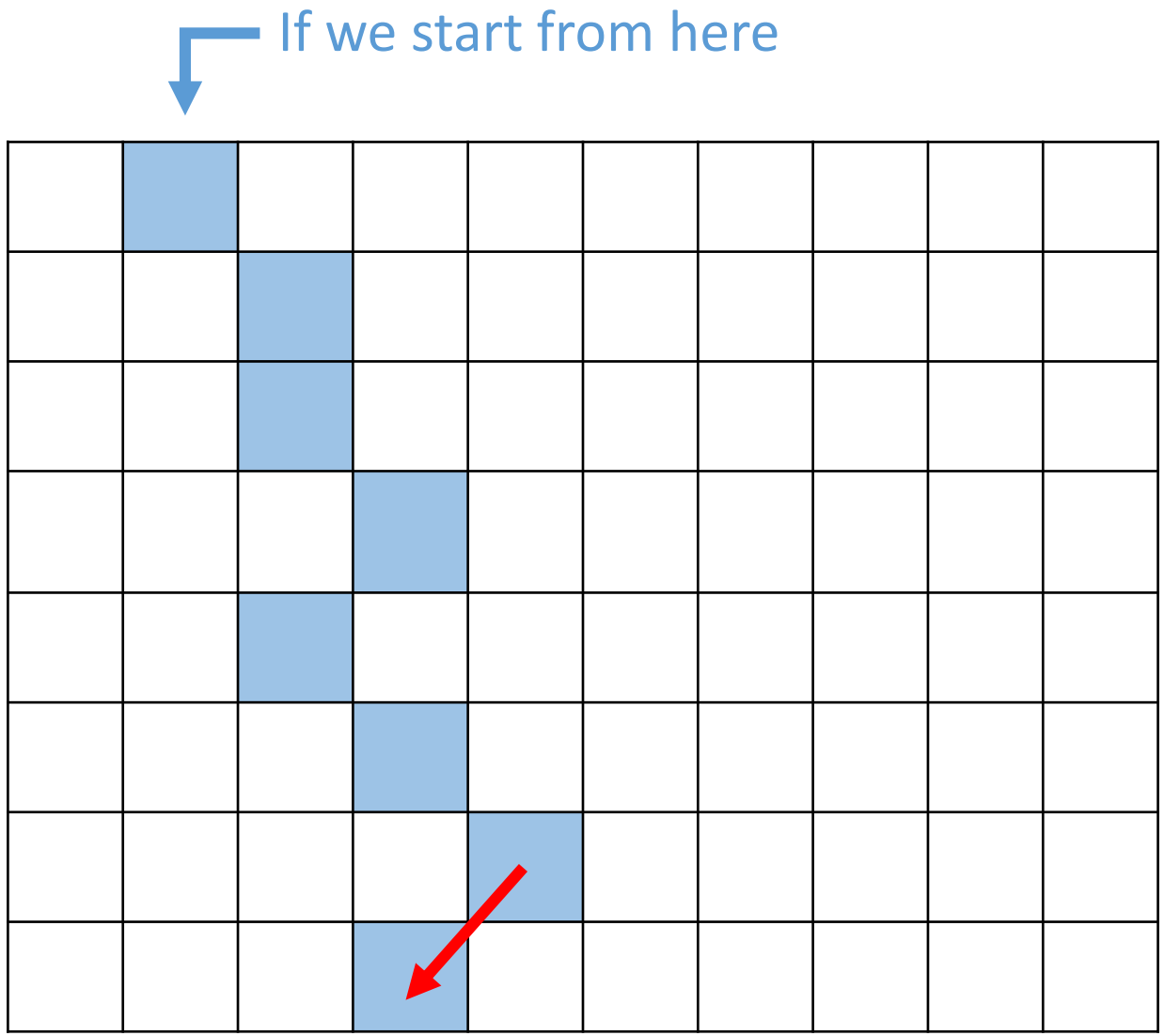


Seam



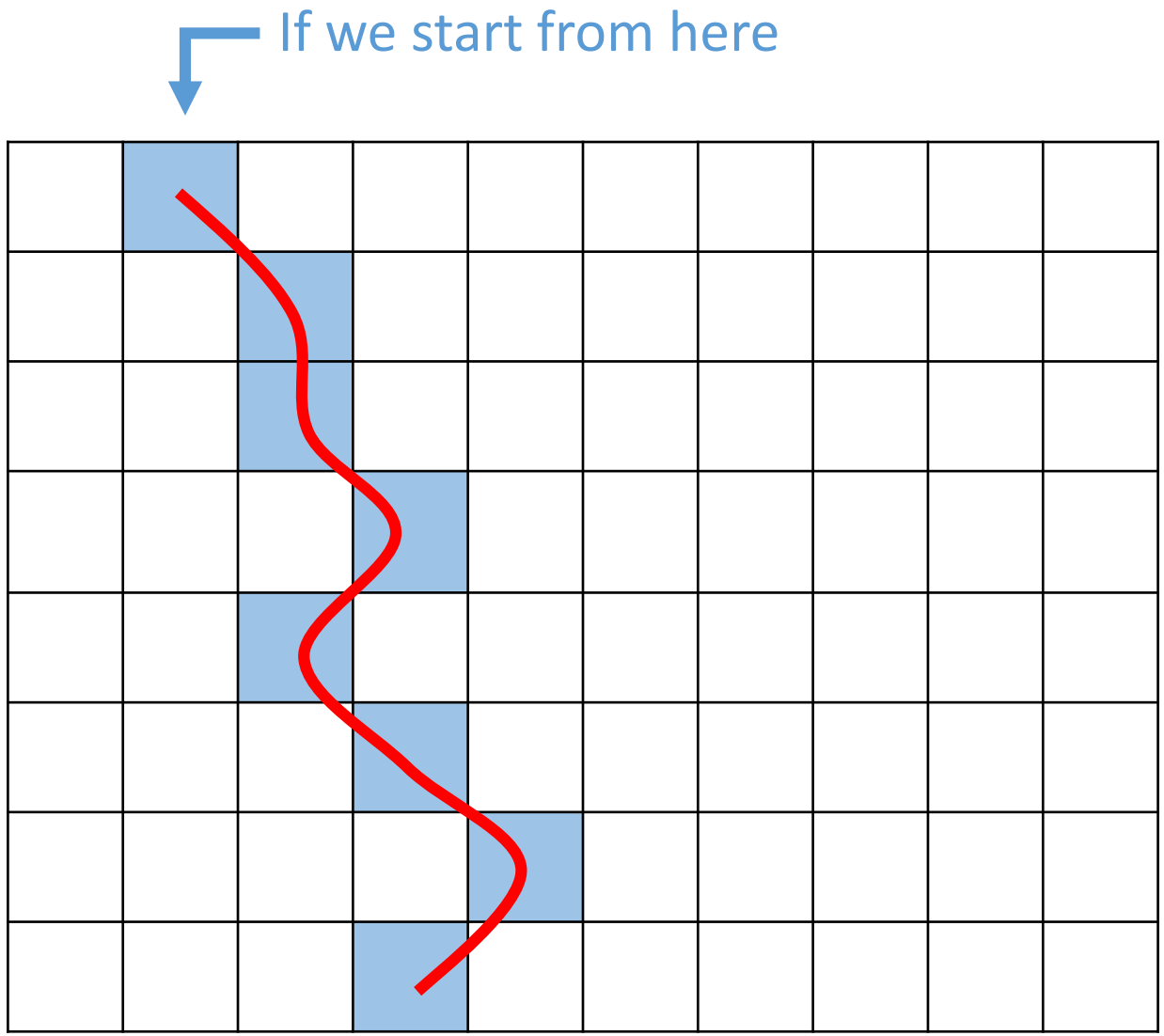
Choose this pixel

Seam



Choose this pixel

Seam



This is one possible seam

Optimal Seam

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

$$s^* = \min_{\mathbf{s}} E(\mathbf{s}) = \min_{\mathbf{s}} \sum_{i=1}^{n} e(\mathbf{I}(s_i))$$

- Find M – minimum energy for all possible seams for each (i, j)
  - Fill in the first row by energy
  - For all row start from second:

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

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

Optimal Seam

Fill in the energy in first row →

M – minimum energy for all possible seams

2	4	3	5	7	6	8	1	3	2

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

Optimal Seam

Add on the minimum energy with possible pixel of 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

M – minimum energy for all possible seams

	2	4	3	5	7	6	8	1	3	2
6										

Optimal Seam

Add on the minimum energy with possible pixel of 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

M – minimum energy for all possible seams

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

Optimal Seam

Add on the minimum energy with possible pixel of seam

M – minimum energy for all possible seams

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

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

Optimal Seam

Add on the minimum energy with possible pixel of 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

M – minimum energy for all possible seams

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

Optimal Seam

Add on the minimum energy with possible pixel of 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

M – minimum energy for all possible seams

2	4	3	5	7	6	8	1	3	2
6	3	6	9	13					

Optimal Seam

Add on the minimum energy with possible pixel of 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

M – minimum energy for all possible seams

2	4	3	5	7	6	8	1	3	2
6	3	6	9	13	7				

Optimal Seam

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

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

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	11	6	9	5	13
…									
…									
…									
…									
57	65	32	69	51	24	36	46	84	48

Optimal Seam

Traverse back and update the seam mask (0 mean a pixel is in the Seam)

Optimal Seam Mask

1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	0	1	1	1	1

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	11	6	9	5	13
…									
…									
…									
…									
57	65	32	69	51	24	36	46	84	48

Optimal Seam

Traverse back and update the seam mask (0 mean a pixel is in the Seam)

Optimal Seam Mask

1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	0	1	1	1
1	1	1	1	1	0	1	1	1	1

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	11	6	9	5	13
…									
…									
…									
…									
57	65	32	69	51	24	36	46	84	48

Optimal Seam

Traverse back and update the seam mask (0 mean a pixel is in the Seam)

Optimal Seam Mask

1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	0	1	1	1	1
1	1	1	1	1	1	0	1	1	1
1	1	1	1	1	0	1	1	1	1

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	11	6	9	5	13
…									
…									
…									
…									
57	65	32	69	51	24	36	46	84	48

Optimal Seam

Traverse back and update the seam mask (0 mean a pixel is in the Seam)

Optimal Seam Mask

1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	0	1	1	1	1	1
1	1	1	1	1	0	1	1	1	1
1	1	1	1	1	1	0	1	1	1
1	1	1	1	1	0	1	1	1	1

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	11	6	9	5	13
…									
…									
…									
…									
57	65	32	69	51	24	36	46	84	48

Optimal Seam

Traverse back and update the seam mask (0 mean a pixel is in the Seam)

Optimal Seam Mask

1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	0	1	1	1	1
1	1	1	1	0	1	1	1	1	1
1	1	1	1	1	0	1	1	1	1
1	1	1	1	1	1	0	1	1	1
1	1	1	1	1	0	1	1	1	1

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	11	6	9	5	13
…									
…									
…									
…									
57	65	32	69	51	24	36	46	84	48

Optimal Seam

Traverse back and update the seam mask (0 mean a pixel is in the Seam)

Optimal Seam Mask

1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	0	1	1	1
1	1	1	1	1	0	1	1	1	1
1	1	1	1	0	1	1	1	1	1
1	1	1	1	1	0	1	1	1	1
1	1	1	1	1	1	0	1	1	1
1	1	1	1	1	0	1	1	1	1

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	11	6	9	5	13
…									
…									
…									
…									
57	65	32	69	51	24	36	46	84	48

Optimal Seam

Traverse back and update the seam mask (0 mean a pixel is in the Seam)

Optimal Seam Mask

1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	0	1	1	1
1	1	1	1	1	1	0	1	1	1
1	1	1	1	1	0	1	1	1	1
1	1	1	1	0	1	1	1	1	1
1	1	1	1	1	0	1	1	1	1
1	1	1	1	1	1	0	1	1	1
1	1	1	1	1	0	1	1	1	1

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	11	6	9	5	13
…									
…									
…									
…									
57	65	32	69	51	24	36	46	84	48

Optimal Seam

Traverse back and update the seam mask (0 mean a pixel is in the Seam)

Optimal Seam Mask

1	1	1	1	1	1	1	0	1	1
1	1	1	1	1	1	0	1	1	1
1	1	1	1	1	1	0	1	1	1
1	1	1	1	1	0	1	1	1	1
1	1	1	1	0	1	1	1	1	1
1	1	1	1	1	0	1	1	1	1
1	1	1	1	1	1	0	1	1	1
1	1	1	1	1	0	1	1	1	1

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	11	6	9	5	13
…									
…									
…									
…									
57	65	32	69	51	24	36	46	84	48

Optimal Seam

Use seam mask to delete the seam from the original image

Optimal Seam Mask

1	1	1	1	1	1	1	0	1	1
1	1	1	1	1	1	0	1	1	1
1	1	1	1	1	1	0	1	1	1
1	1	1	1	1	0	1	1	1	1
1	1	1	1	0	1	1	1	1	1
1	1	1	1	1	0	1	1	1	1
1	1	1	1	1	1	0	1	1	1
1	1	1	1	1	0	1	1	1	1

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	11	6	9	5	13
…									
…									
…									
…									
57	65	32	69	51	24	36	46	84	48

Optimal seam with minimum energy

Implementation

- Calculate gradient of pixel in *energyRGB.m*
- Find optimal seam in *findOptSeam.m*
  - *Demo point: show the first optimal seam energy*
- Reduce pixels by input mask in *reduceImageByMask.m*