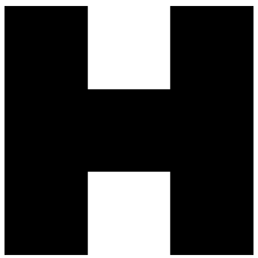
Lab Nov 1st

template matching

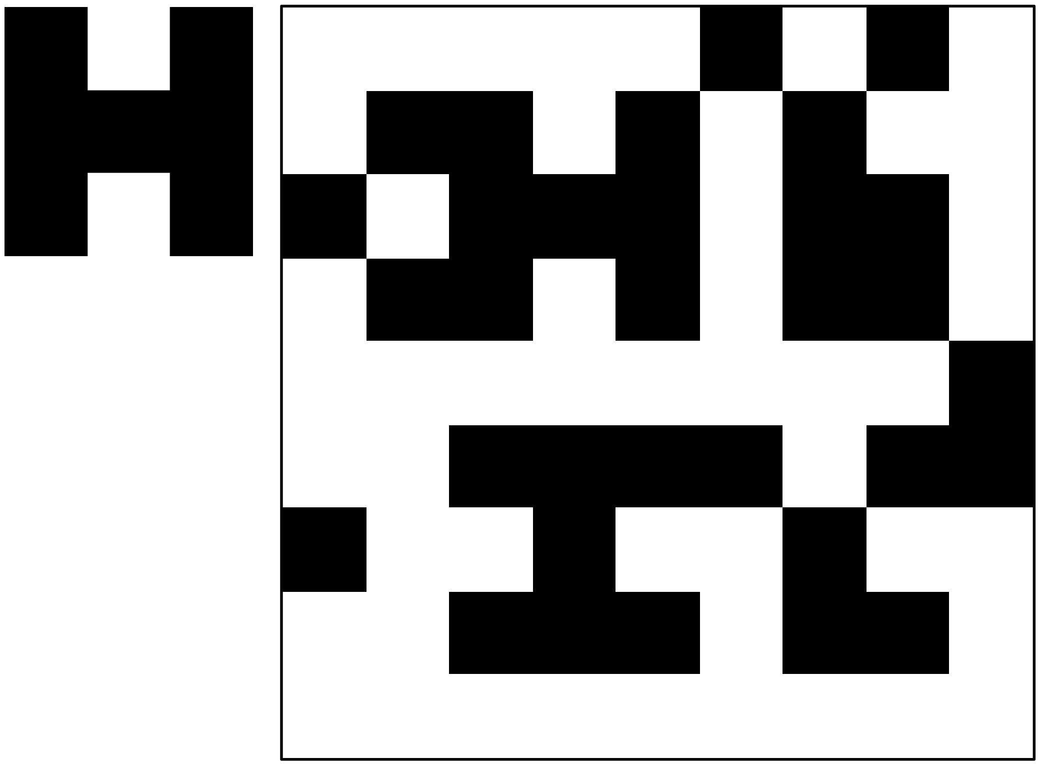
- given a sample image section (template)
  - find closest match in another image

- Move template over image

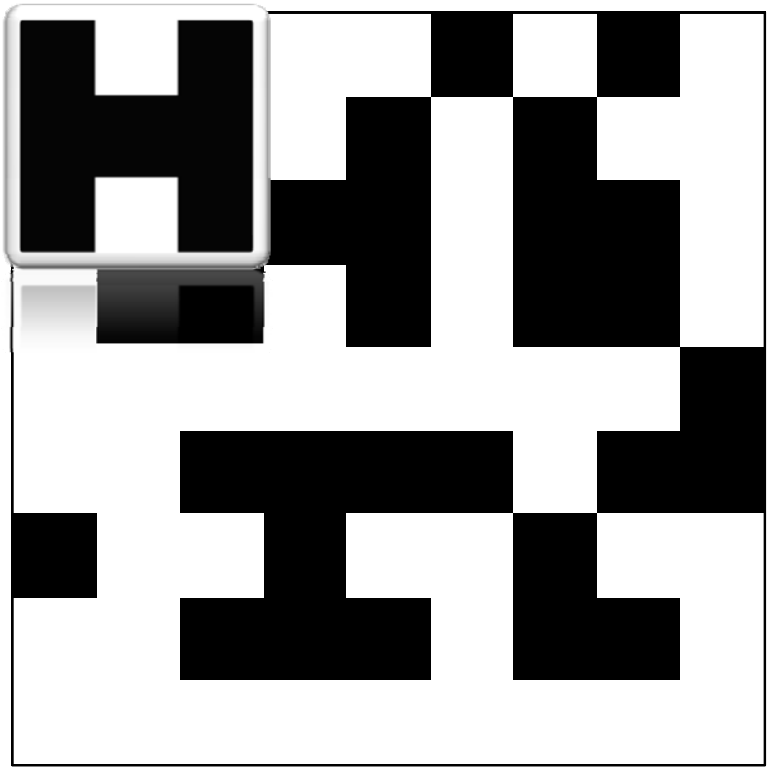
move template over image



move template over image

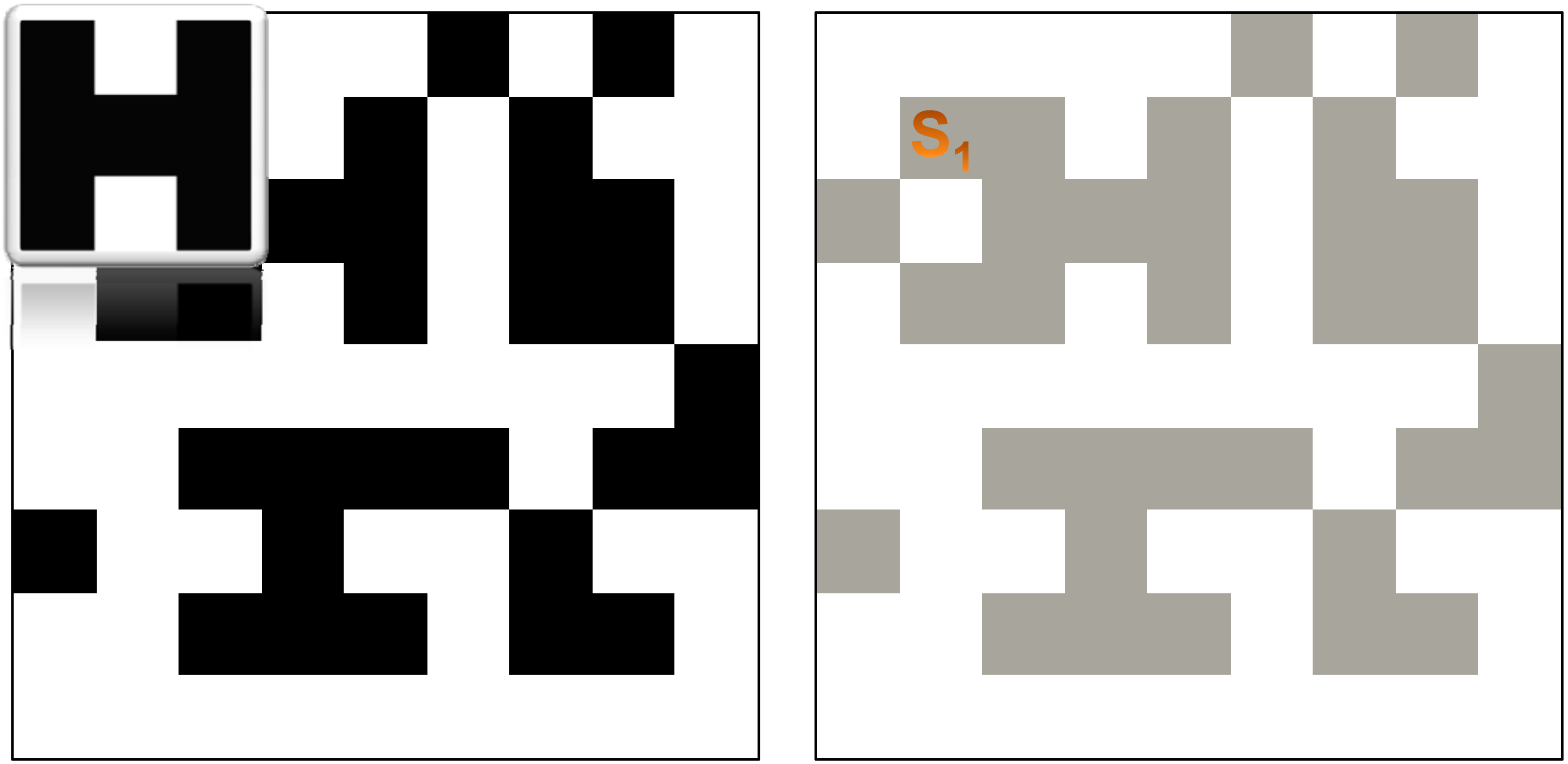


move template over image



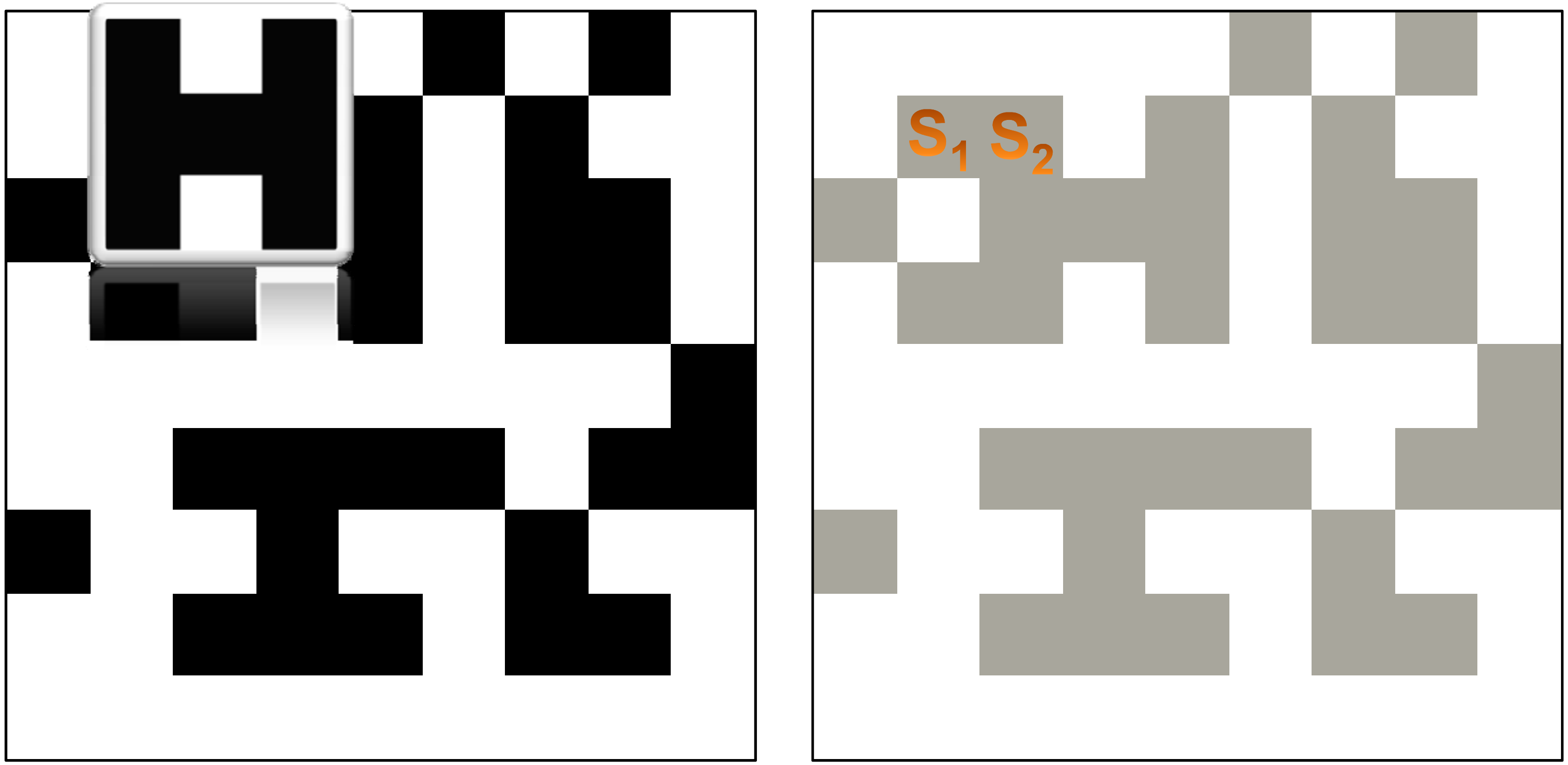
Calculate similarity at this point

move template over image



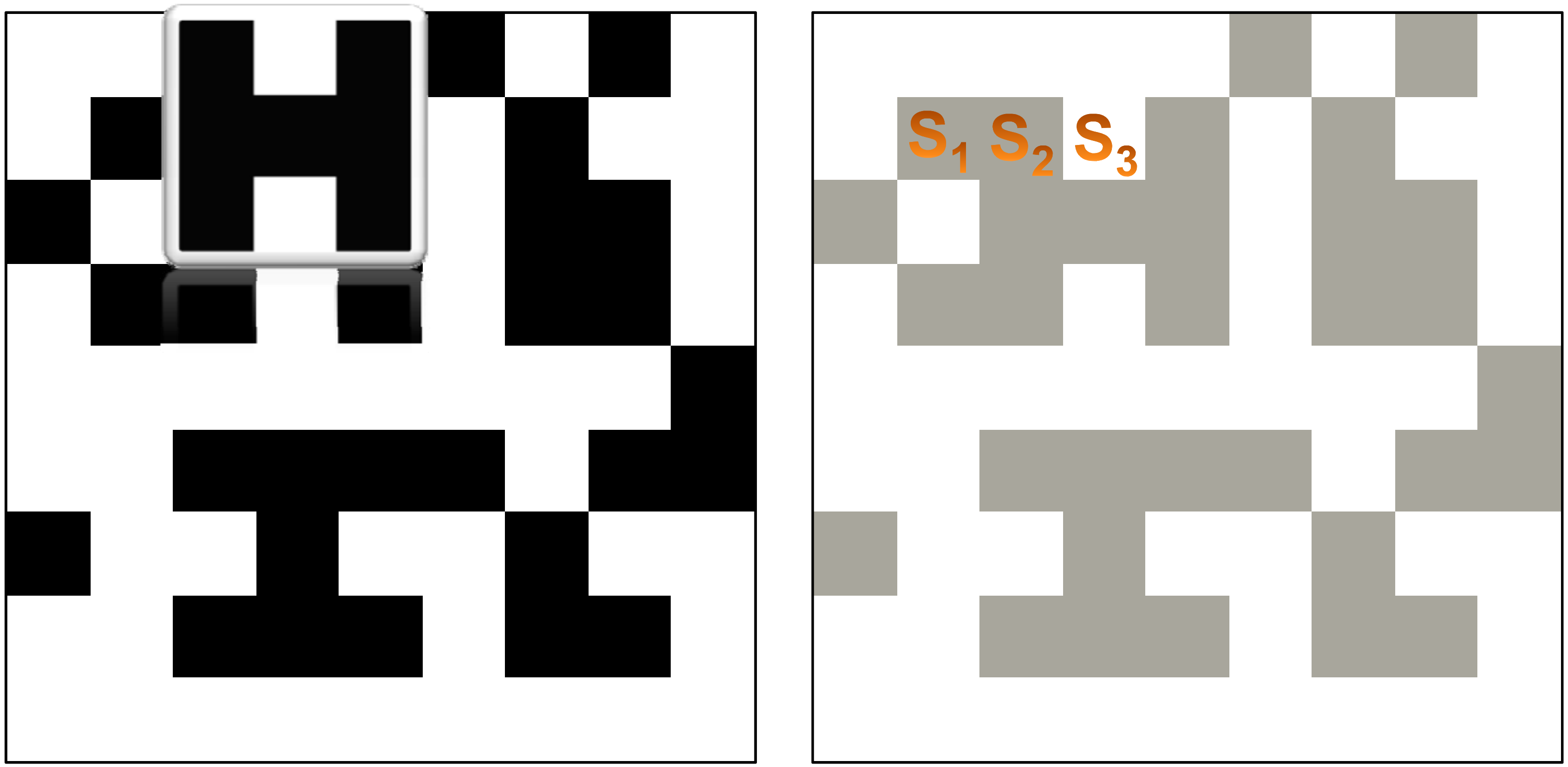
Calculate similarity at this point

move template over image



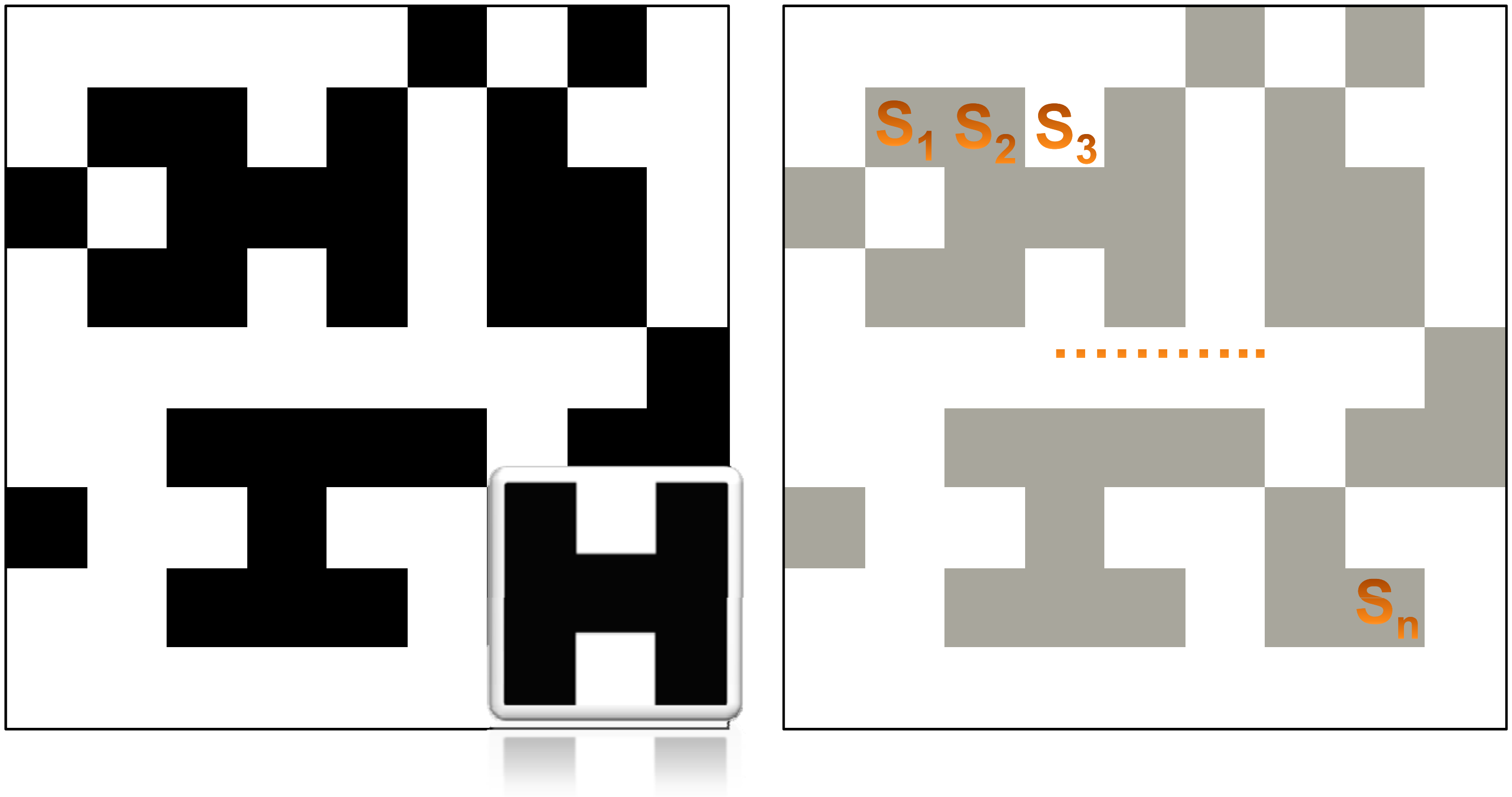
Calculate similarity at this point

move template over image



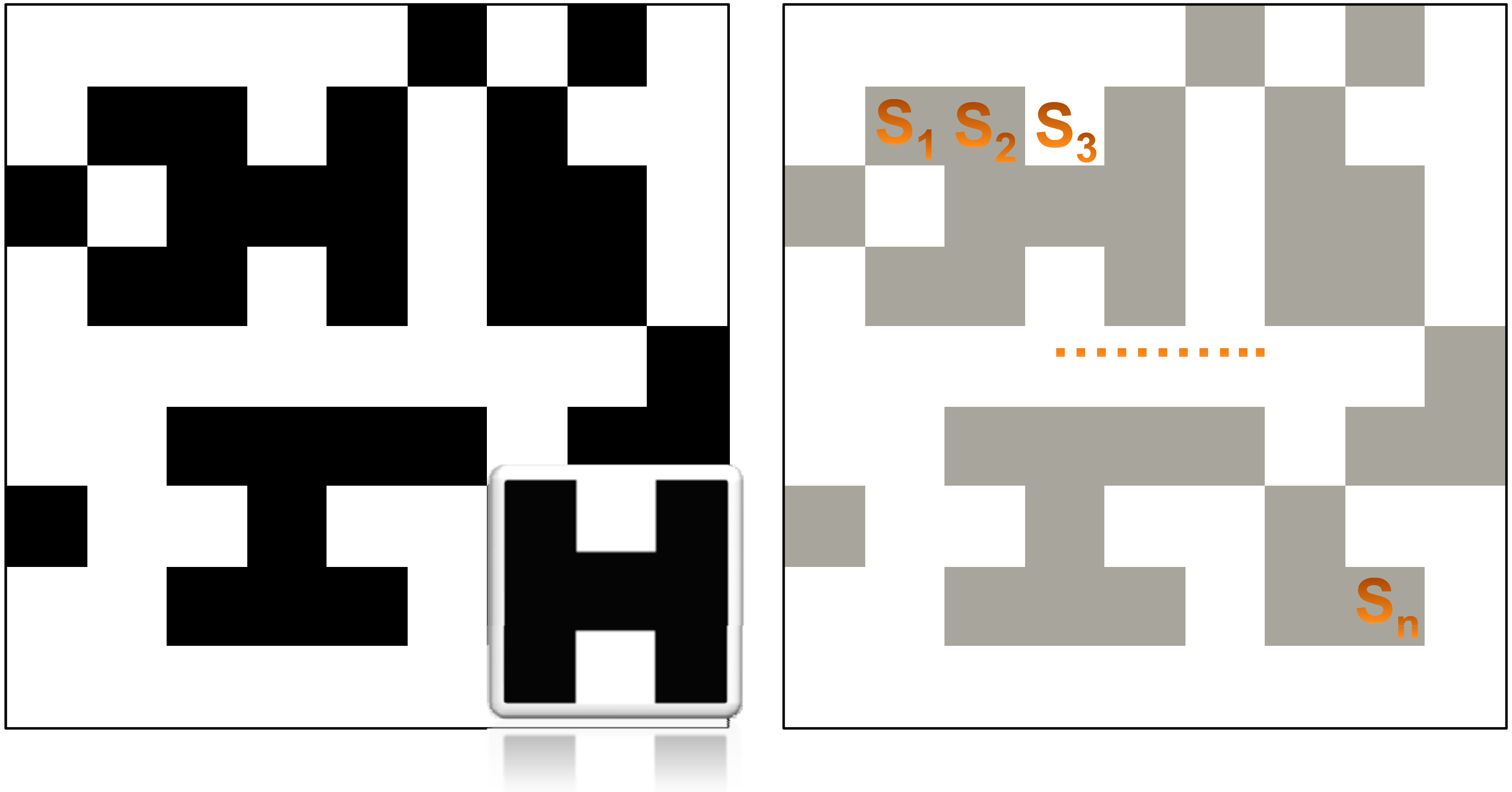
Calculate similarity at this point

move template over image



Calculate similarity at this point

move template over image



Similarity is best(Sk), 1 <= k <= n

template matching

- given a sample image section (template)
  - find closest match in another image
- Move template over image
- Key point:
  - Similarity metric

similarity metrics…

- correlation
  - Euclidean distance

$$d(a,b) = \sqrt{\sum_{r=1}^{n} (a_r - b_r)^2}$$

similarity metrics…

- correlation
  - Euclidean distance

$$d(a,b) = \sqrt{\sum_{r=1}^{n} (a_r - b_r)^2}$$

  - for image templates…
    - each value in template is like a dimension

$$d(y) = \sqrt{\sum_{\Omega} \left(f(\Omega) - t(\Omega - y) \right)^2}$$

similarity metrics…

- correlation
  - Euclidean distance

$$d(a,b)=\sqrt{\sum_{r=1}^{n}(a_r-b_r)^2}$$

  - for image templates…
    - each value in template is like a dimension
    - In our case..

$$d(y)=\sqrt{\sum_{\Omega}\left(f(\Omega)-t(\Omega-y)\right)^2}$$

$$d(x,y)=\sqrt{\sum_{\bar{x}}^{|f|}\sum_{\bar{y}}^{|f|}\left(f(\bar{x},\bar{y})-t(\bar{x}-x,\bar{y}-y)\right)^2}$$

similarity metrics…

$$d(x,y)=\sqrt{\sum_{\bar{x}}^{|f|}\sum_{\bar{y}}^{|f|}\left(f(\bar{x},\bar{y})-t(\bar{x}-x,\bar{y}-y)\right)^2}$$

similarity metrics…

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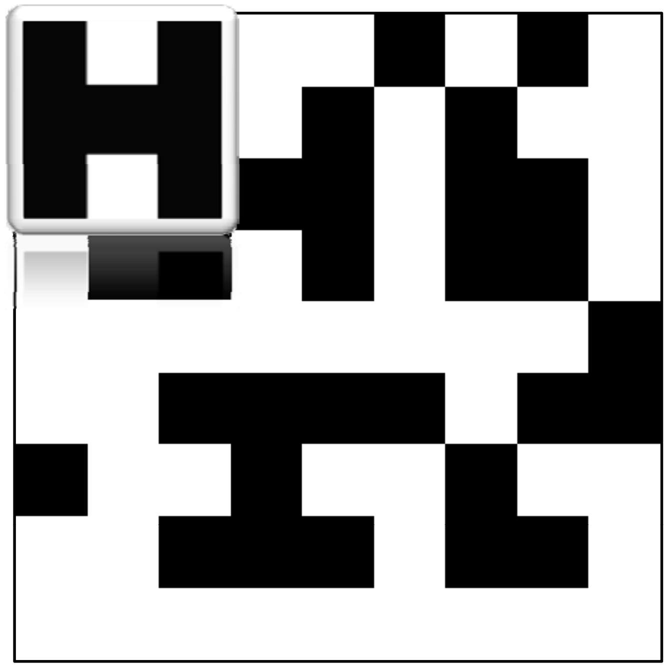
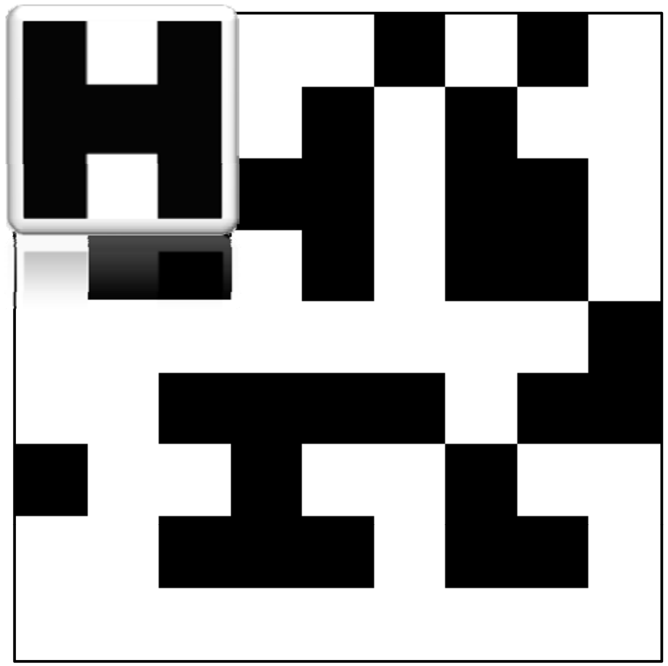
- move template over image
- for each location get similarity



similarity metrics…

$$d(x,y)=\sqrt{\sum_{\bar{x}}^{|f|}\sum_{\bar{y}}^{|f|}\left(f(\bar{x},\bar{y})-t(\bar{x}-x,\bar{y}-y)\right)^2}$$

- move template over image
- for each location get similarity
  - for each overlapping pixel
    - subtract and square
    - sum them all



similarity metrics...

$$d(x,y) = \sqrt{\sum_{\bar{x}}^{|f|} \sum_{\bar{y}}^{|f|} \left(f(\bar{x},\bar{y}) - t(\bar{x}-x, \bar{y}-y) \right)^2}$$

- move template over image
- for each location get similarity
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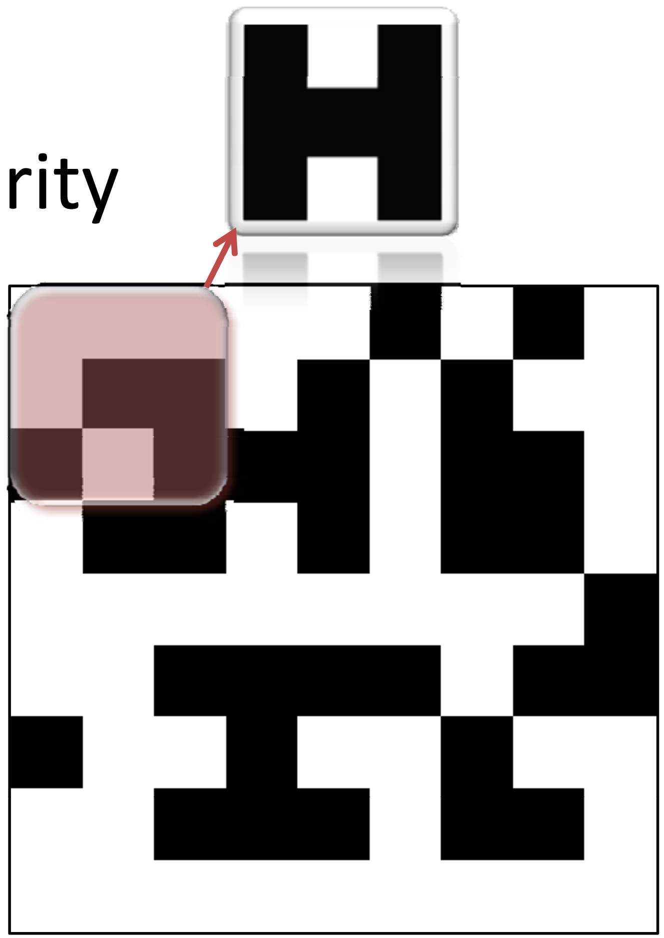
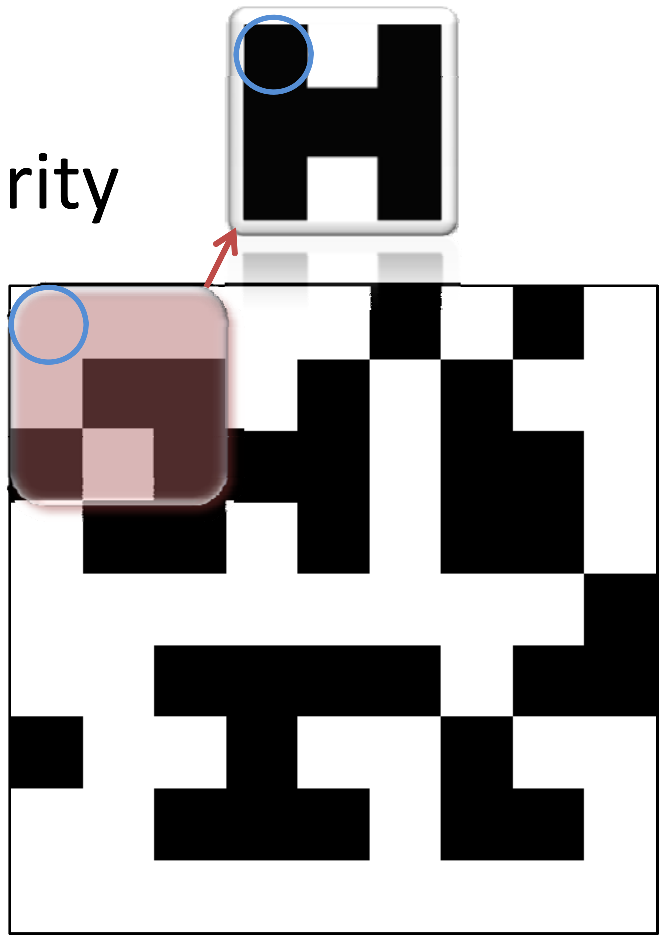


similarity metrics...

$$d(x,y)=\sqrt{\sum_{\bar{x}}^{|f|}\sum_{\bar{y}}^{|f|}\left(f(\bar{x},\bar{y})-t(\bar{x}-x,\bar{y}-y)\right)^2}$$

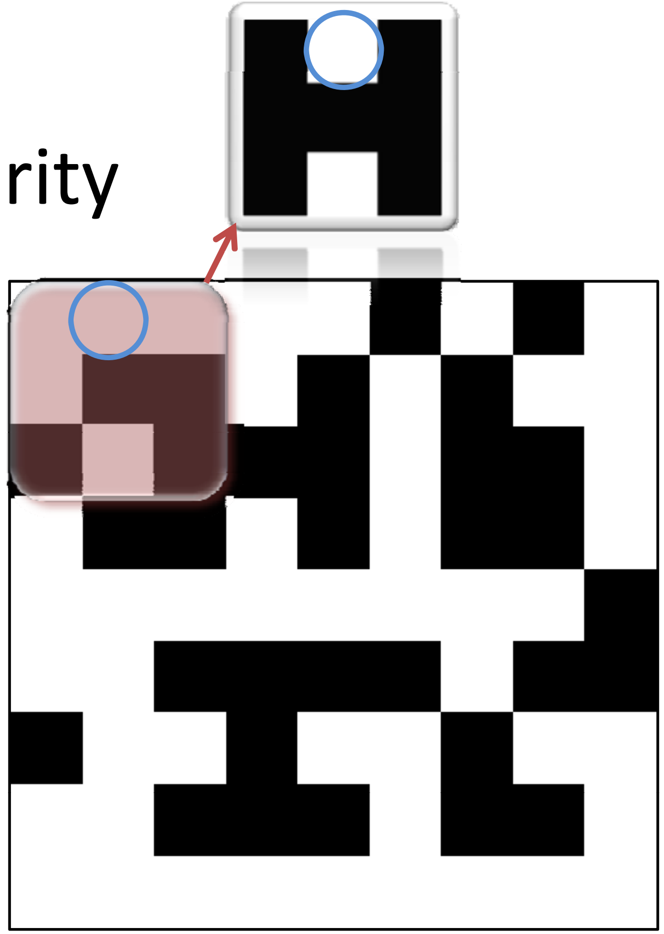
- move template over image
- for each location get similarity
  - for each overlapping pixel
    - subtract and square
    - sum them all
- $(1-0)^2=1$
- Sum: 1



similarity metrics…

$$d(x,y)=\sqrt{\sum_{\bar{x}}^{|f|}\sum_{\bar{y}}^{|f|}\left(f(\bar{x},\bar{y})-t(\bar{x}-x,\bar{y}-y)\right)^2}$$

- move template over image
- for each location get similarity
  - for each overlapping pixel
    - subtract and square
    - sum them all

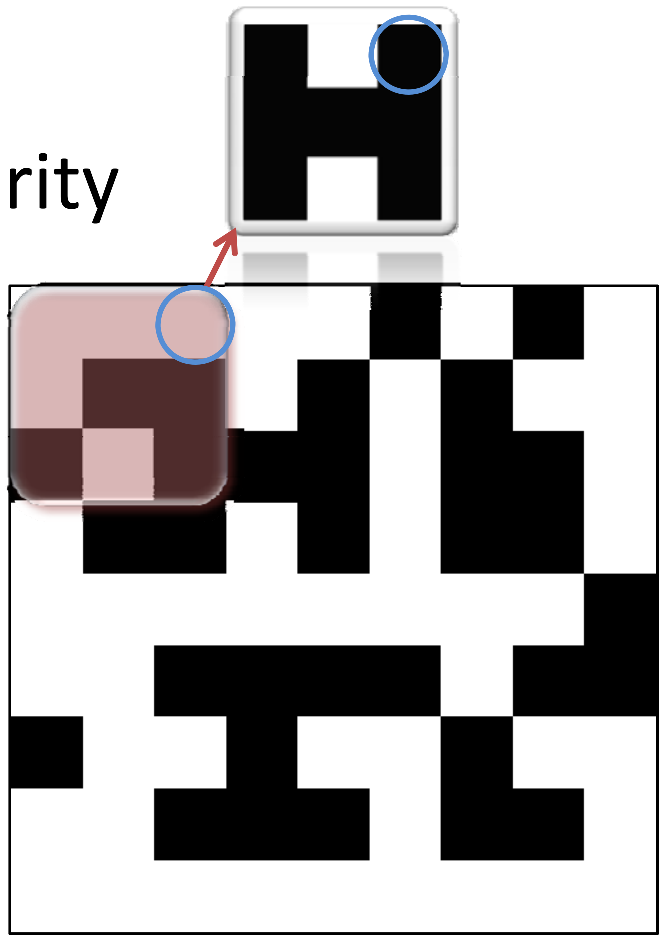


- Sum: 1+0

similarity metrics…

$$d(x,y)=\sqrt{\sum_{\bar{x}}^{|f|}\sum_{\bar{y}}^{|f|}\left(f(\bar{x},\bar{y})-t(\bar{x}-x,\bar{y}-y)\right)^2}$$

- move template over image
- for each location get similarity
  - – for each overlapping pixel
    - subtract and square
    - sum them all



- Sum: 1+0+1

similarity metrics…

$$d(x,y)=\sqrt{\sum_{\bar{x}}^{|f|}\sum_{\bar{y}}^{|f|}\left(f(\bar{x},\bar{y})-t(\bar{x}-x,\bar{y}-y)\right)^2}$$

- move template over image
- for each location get similarity
  - for each overlapping pixel
    - subtract and square
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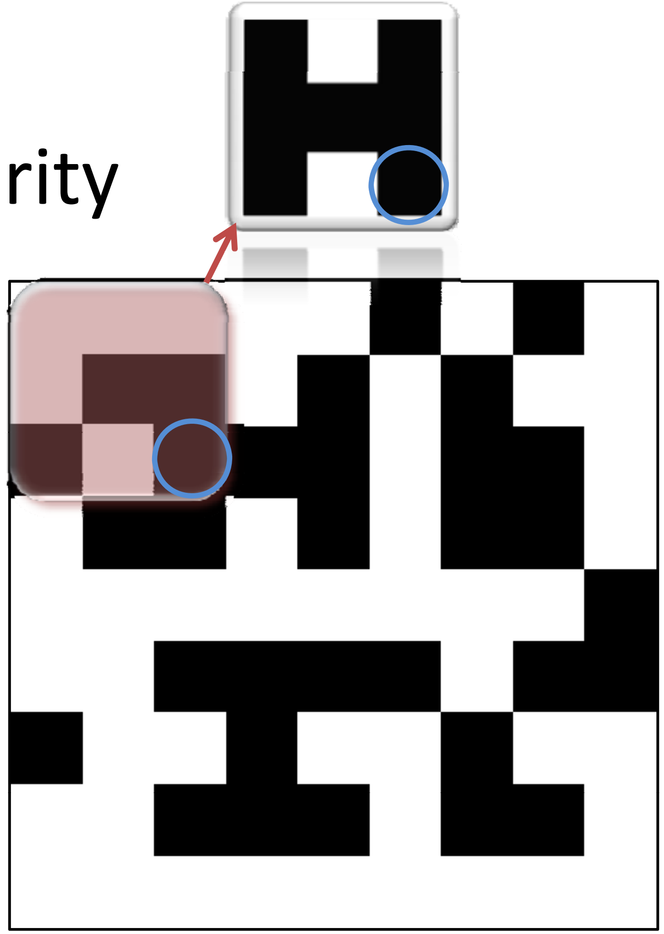


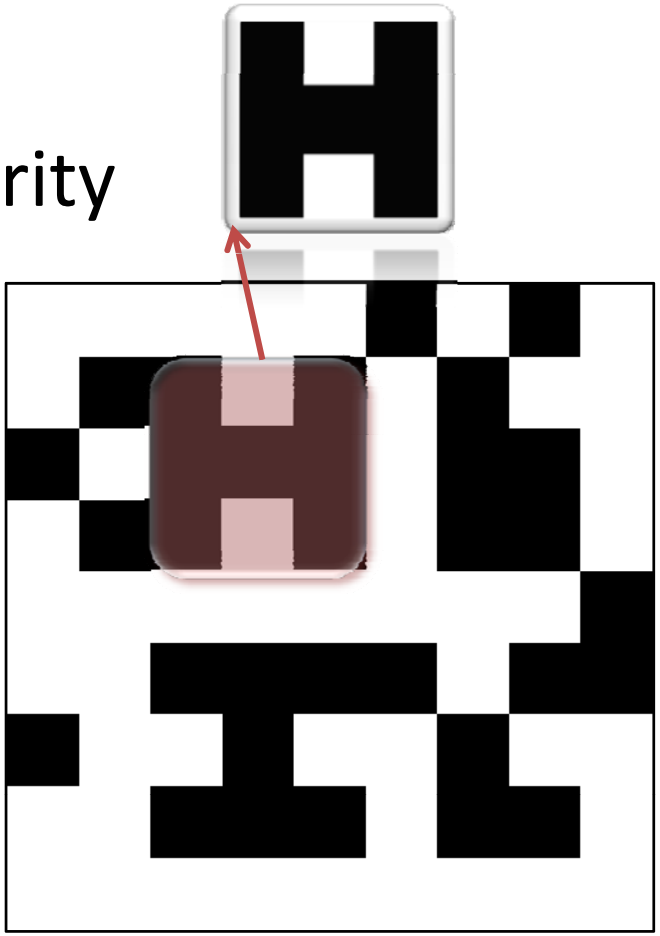
- Sum: 1+0+1+1+0+0+0+0+0

  = 3

similarity metrics…

$$d(x,y)=\sqrt{\sum_{\bar{x}}^{|f|}\sum_{\bar{y}}^{|f|}\left(f(\bar{x},\bar{y})-t(\bar{x}-x,\bar{y}-y)\right)^2}$$

- move template over image
- for each location get similarity
  - for each overlapping pixel
    - subtract and square
    - sum them all

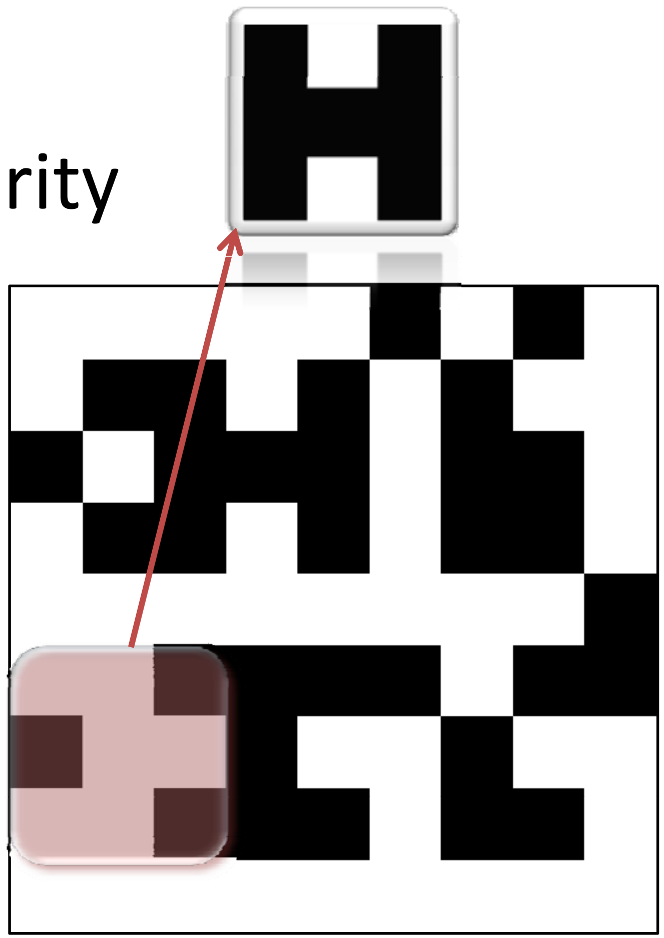


- Sum: 0+0+0+0+0+0+0+0+0
  = 0

similarity metrics…

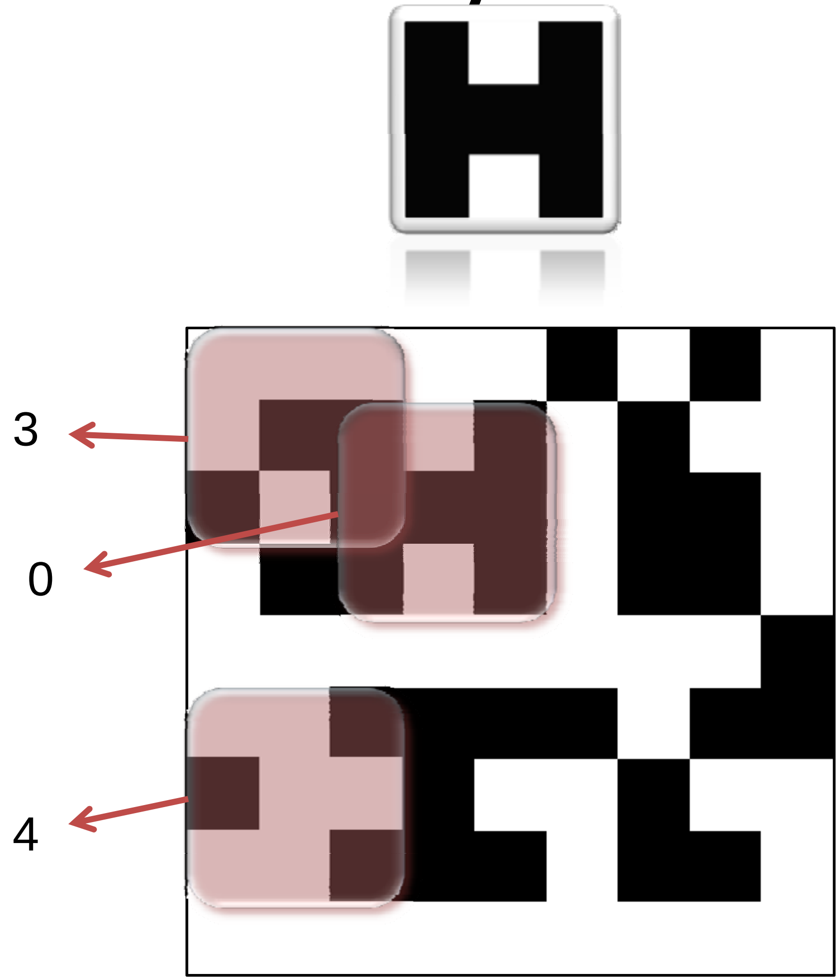
$$d(x, y) = \sqrt{\sum_{\bar{x}}^{|f|} \sum_{\bar{y}}^{|f|} \left(f(\bar{x}, \bar{y}) - t(\bar{x} - x, \bar{y} - y) \right)^2}$$

- move template over image
- for each location get similarity
  - for each overlapping pixel
    - subtract and square
    - sum them all



- Sum: 1+0+0+0+1+1+1+0+0
  = 4

similarity metrics...



problems...

$$d(y) = \sqrt{\sum_{\Omega} \left(f(\Omega) - t(\Omega - y) \right)^2}$$

- slow! squares and square roots

problems...

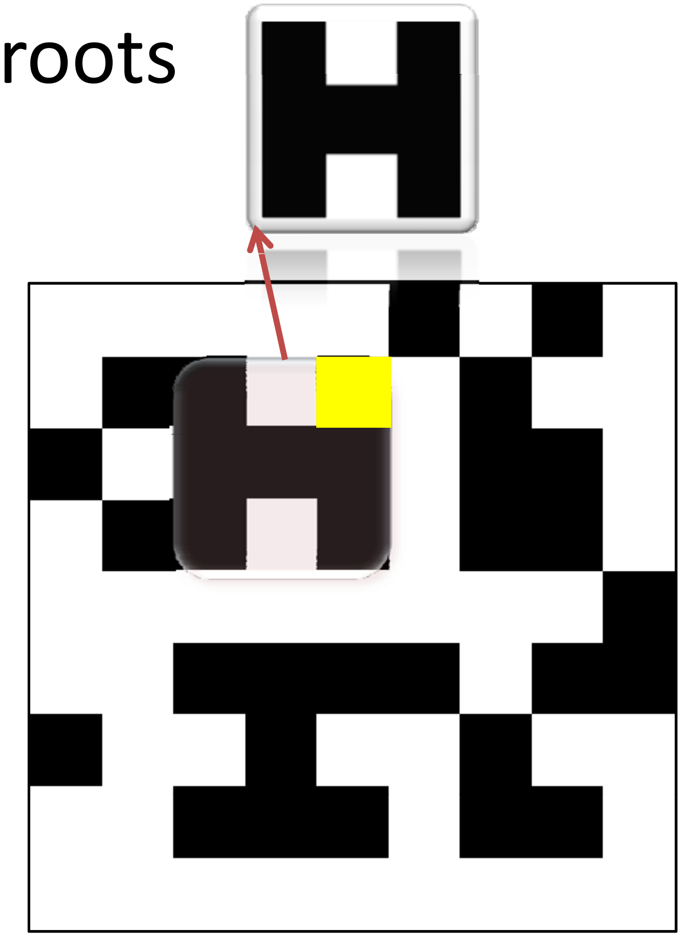
$$d(y)=\sqrt{\sum_{\Omega}\left(f(\Omega)-t(\Omega-y)\right)^2}$$

- slow! squares and square roots
- very subject to noise

problems...

$$d(y) = \sqrt{\sum_{\Omega} \left(f(\Omega) - t(\Omega - y) \right)^2}$$

- slow! squares and square roots
- very subject to noise
  - say, yellow= intensity 8
  - difference becomes huge!



solutions

$$d(y) = \sqrt{\sum_{\Omega} \left(f(\Omega) - t(\Omega - y) \right)^2}$$

- slow! squares and square roots

solutions

$$d(y) = \sqrt{\sum_{\Omega} \left(f(\Omega) - t(\Omega - y) \right)^2}$$

- slow! squares and square roots
  - use distance squared $$d(y)^2 = \sum_{\Omega} \left(f(\Omega) - t(\Omega - y) \right)^2$$

solutions

$$d(y) = \sqrt{\sum_{\Omega} \left(f(\Omega) - t(\Omega - y) \right)^2}$$

- slow! squares and square roots
  - use distance squared $d(y)^2 = \sum_{\Omega} \left(f(\Omega) - t(\Omega - y) \right)^2$
  - notice... expand, and..

$$d(y)^2 = \sum_{\Omega} \left(f(\Omega) - t(\Omega - y) \right)^2 = \sum_{\Omega} \left(f(\Omega)^2 - 2 f(\Omega) t(\Omega - y) + t(\Omega - y)^2 \right)$$

solutions

$$d(y) = \sqrt{\sum_{\Omega} \left(f(\Omega) - t(\Omega - y) \right)^2}$$

- slow! squares and square roots
  - use distance squared $$d(y)^2 = \sum_{\Omega} \left(f(\Omega) - t(\Omega - y) \right)^2$$
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  - constant values do not change between regions/pixels
    - why is this important?

solutions

– constant values do not change between regions/pixels

$$d(y)^2 = \sum_{\Omega} \left(f(\Omega) - t(\Omega - y) \right)^2 = \sum_{\Omega} \left(f(\Omega)^2 - 2 f(\Omega) t(\Omega - y) + t(\Omega - y)^2 \right)$$

solutions

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$$d(y)^2 = \sum_{\Omega}\left(f(\Omega) - t(\Omega - y)\right)^2 = \sum_{\Omega}\left(f(\Omega)^2 - 2f(\Omega)t(\Omega - y) + t(\Omega - y)^2\right)$$

– $t(\Omega - y)^2$ (template portion squared) is constant because the template doesn't change

solutions

- constant values do not change between regions/pixels

$$d(y)^2 = \sum_{\Omega} \left(f(\Omega) - t(\Omega - y) \right)^2 = \sum_{\Omega} \left(f(\Omega)^2 - 2f(\Omega)t(\Omega - y) + t(\Omega - y)^2 \right)$$

- $t(\Omega - y)^2$ (template portion squared) is constant because the template doesn't change
- $f(\Omega)^2$ (image portion squared) is approximately constant IF…

solutions

– constant values do not change between regions/pixels

$$d(y)^2 = \sum_{\Omega} \left(f(\Omega) - t(\Omega - y) \right)^2 = \sum_{\Omega} \left(f(\Omega)^2 - 2 f(\Omega) t(\Omega - y) + t(\Omega - y)^2 \right)$$

– $t(\Omega - y)^2$ (template portion squared) is constant because the template doesn't change

– $f(\Omega)^2$ (image portion squared) is approximately constant IF…

  - the template brightness is similar throughout the image

solutions

– constant values do not change between regions/pixels

$$d(y)^2 = \sum_{\Omega}\left(f(\Omega) - t(\Omega - y)\right)^2 = \sum_{\Omega}\left(f(\Omega)^2 - 2f(\Omega)t(\Omega - y) + t(\Omega - y)^2\right)$$

– $t(\Omega - y)^2$ (template portion squared) is constant because the template doesn't change

– $f(\Omega)^2$ (image portion squared) is approximately constant IF…

- the template brightness is similar throughout the image
- when does this fail?

solutions

- constant values do not change between regions/pixels

$$d(y)^2 = \sum_{\Omega}\left(f(\Omega) - t(\Omega - y)\right)^2 = \sum_{\Omega}\left(f(\Omega)^2 - 2f(\Omega)t(\Omega - y) + t(\Omega - y)^2\right)$$

- $t(\Omega - y)^2$ (template portion squared) is constant because the template doesn't change
- $f(\Omega)^2$ (image portion squared) is approximately constant IF…
  - the template brightness is similar throughout the image
  - when does this fail?

- new similarity metric

$$d(y) = \sum_{\Omega} f(\Omega)t(\Omega - y)$$

solutions

– constant values do not change between regions/pixels

$$d(y)^2 = \sum_{\Omega}\left(f(\Omega) - t(\Omega - y)\right)^2 = \sum_{\Omega}\left(f(\Omega)^2 - 2f(\Omega)t(\Omega - y) + t(\Omega - y)^2\right)$$

– $t(\Omega - y)^2$ (template portion squared) is constant because the template doesn't change

– $f(\Omega)^2$ (image portion squared) is approximately constant IF…

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- new similarity metric

$$d(y) = \sum_{\Omega} f(\Omega)t(\Omega - y)$$

cross correlation

cross correlation

$$d(y) = \sum_{\Omega} f(\Omega) t(\Omega - y)$$

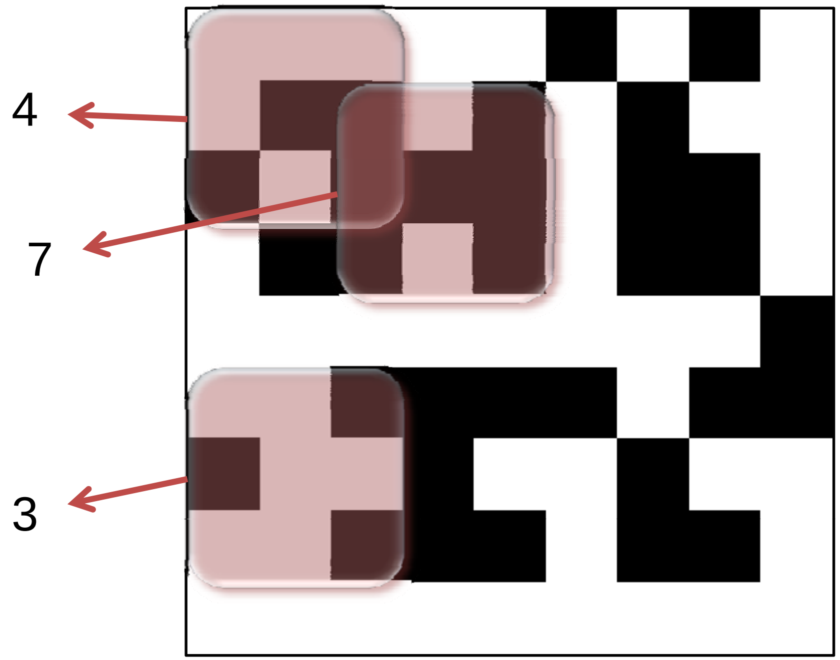
– fast!

cross correlation

$$d(y) = \sum_{\Omega} f(\Omega) t(\Omega - y)$$

– fast!

– maximal when identical



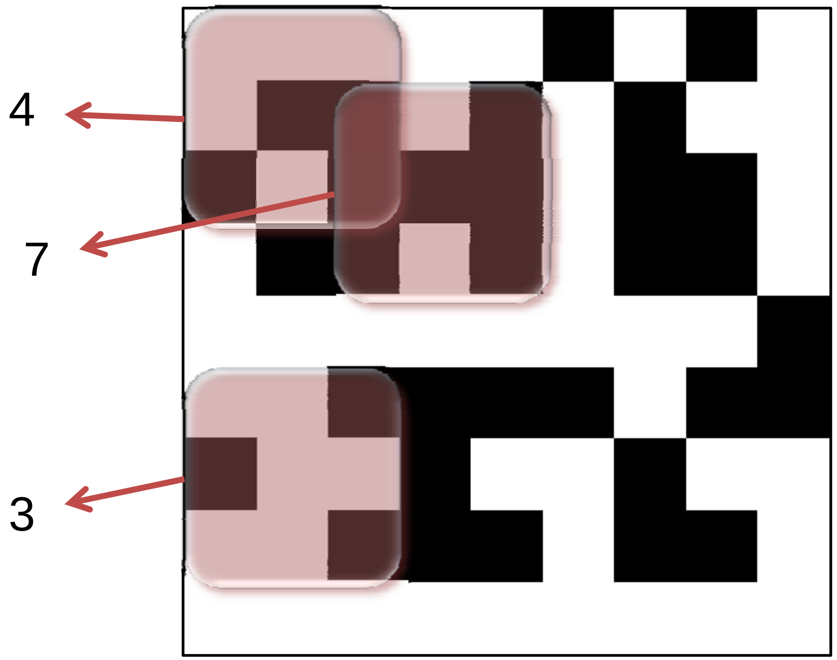
cross correlation

$$d(y) = \sum_{\Omega} f(\Omega) t(\Omega - y)$$

– fast!

– maximal when identical

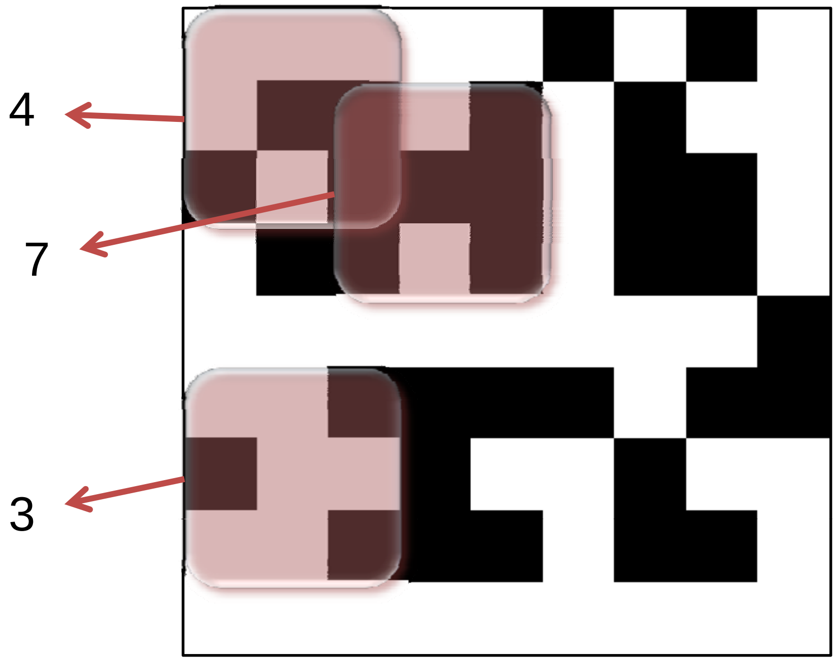
– Really?



cross correlation

$$d(y) = \sum_{\Omega} f(\Omega) t(\Omega - y)$$

- fast!
- maximal when identical
- Really?
  - if I compare with solid black region, I also get 7.
  - Why?



cross correlation

$$d(y) = \sum_{\Omega} f(\Omega) t(\Omega - y)$$

– fast!

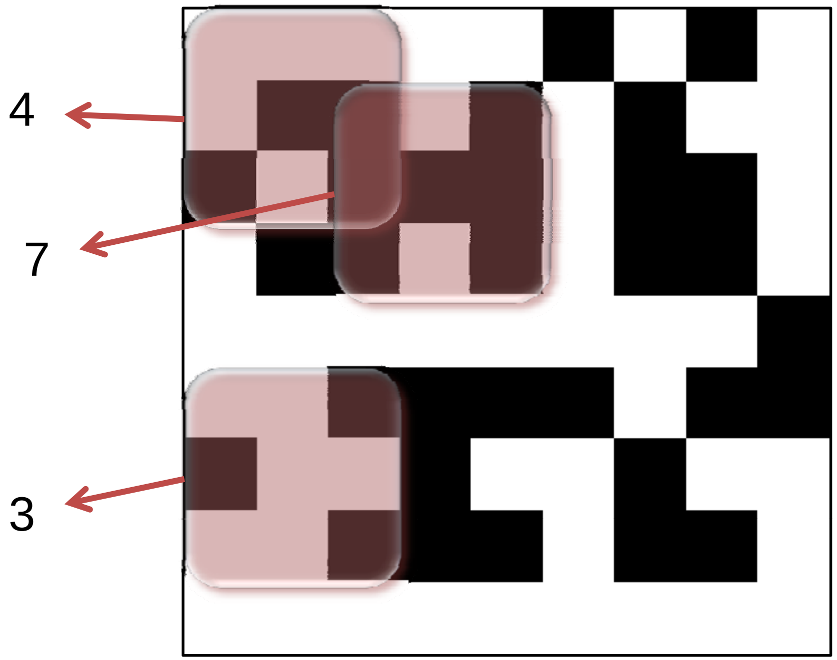
– maximal when identical

– Really?

- if I compare with solid black region, I also get 7.
- Why?

– my assumption about near-constant image brightness is violated!

– less impact with larger templates, larger range



handout

handout

- Template

1	0	1
1	1	1
1	0	1

images

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

0	1	0	1	1
1	1	1	1	3
0	1	0	4	1
0	1	0	1	0
2	2	1	5	1

euclid^2

3	5	3	x	x
6	0	6	x	x
3	5	4	x	x
x	x	x	x	x
x	x	x	x	x

6	9	23	x	x
6	11	18	x	x
10	28	44	x	x
x	x	x	x	x
x	x	x	x	x

cross correlation

5	4	5	x	x
3	7	3	x	x
5	4	5	x	x
x	x	x	x	x
x	x	x	x	x

3	10	7	x	x
3	9	9	x	x
4	14	4	x	x
x	x	x	x	x
x	x	x	x	x

what about this noise problem??

- normalize!
- normalized cross correlation

- next lab