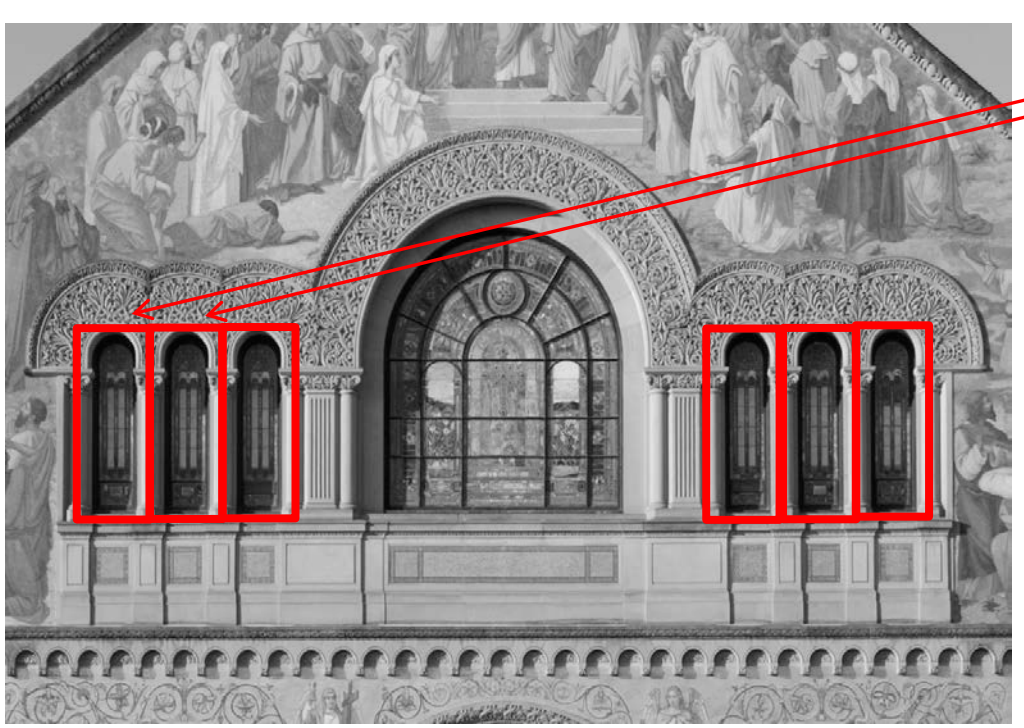
Template matching

- Problem: locate an object, described by a template $t[x,y]$, in the image $s[x,y]$
- Example



$s[x,y]$

$t[x,y]$

Template matching (cont.)

- Search for the best match by minimizing mean-squared error

$$E[p,q] = \sum_{x=-\infty}^{\infty}\sum_{y=-\infty}^{\infty}\left[s[x,y]-t[x-p,y-q]\right]^2$$

$$= \sum_{x=-\infty}^{\infty}\sum_{y=-\infty}^{\infty}\left|s[x,y]\right|^2 + \sum_{x=-\infty}^{\infty}\sum_{y=-\infty}^{\infty}\left|t[x,y]\right|^2 - 2\sum_{x=-\infty}^{\infty}\sum_{y=-\infty}^{\infty}s[x,y]\cdot t[x-p,y-q]$$

- Equivalently, maximize *area correlation*

$$r[p,q] = \sum_{x=-\infty}^{\infty}\sum_{y=-\infty}^{\infty}s[x,y]\cdot t[x-p,y-q] = s[p,q]*t[-p,-q]$$

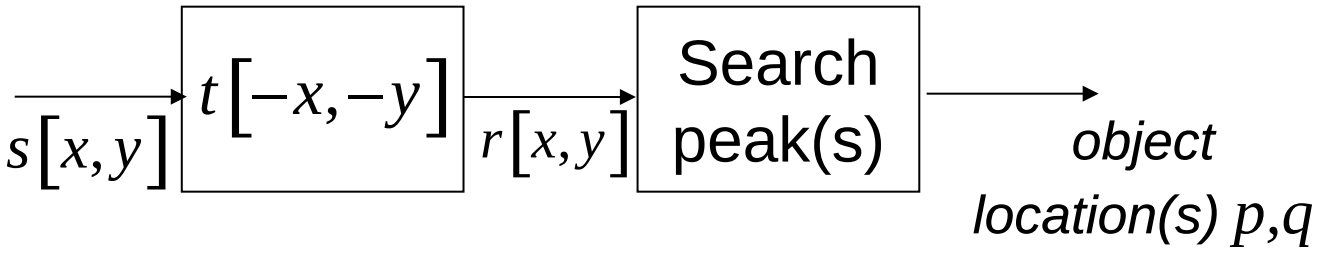
- Area correlation is equivalent to convolution of image $s[x,y]$ with impulse response $t[-x,-y]$

Template matching (cont.)

- From Cauchy-Schwarz inequality

$$r[p,q]=\sum_{x=-\infty}^{\infty}\sum_{y=-\infty}^{\infty}s[x,y]\cdot t[x-p,y-q]\le\sqrt{\left(\sum_{x=-\infty}^{\infty}\sum_{y=-\infty}^{\infty}|s[x,y]|^2\right)\left(\sum_{x=-\infty}^{\infty}\sum_{y=-\infty}^{\infty}|t[x,y]|^2\right)}$$

- Equality, iff $s[x,y]=\alpha\cdot t[x-p,y-q]$ with $\alpha\ge 0$
- Block diagram of template matcher

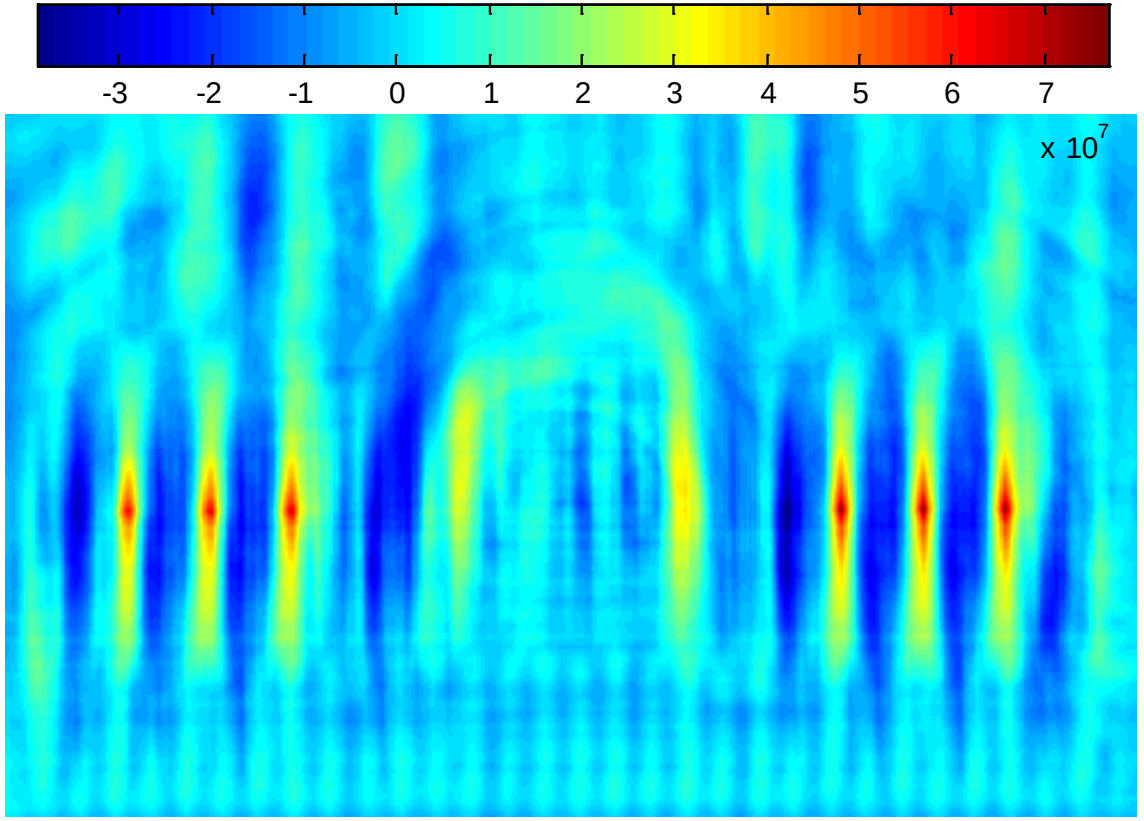


- Remove mean before template matching to avoid bias towards bright image areas

Template matching example

$t[x,y]$

$s[x,y]$



$r[p,q]$