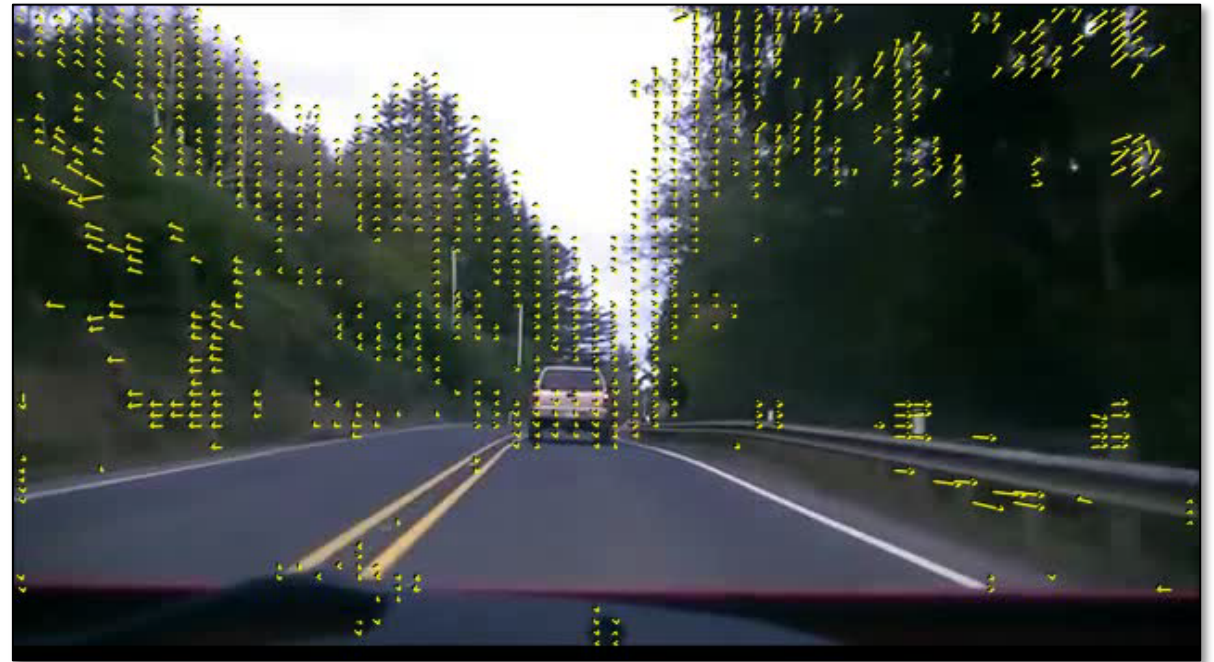


Displacement estimation

- Displacement estimation by block matching
 - Search strategies
 - Subpixel estimation



Where is the defect?

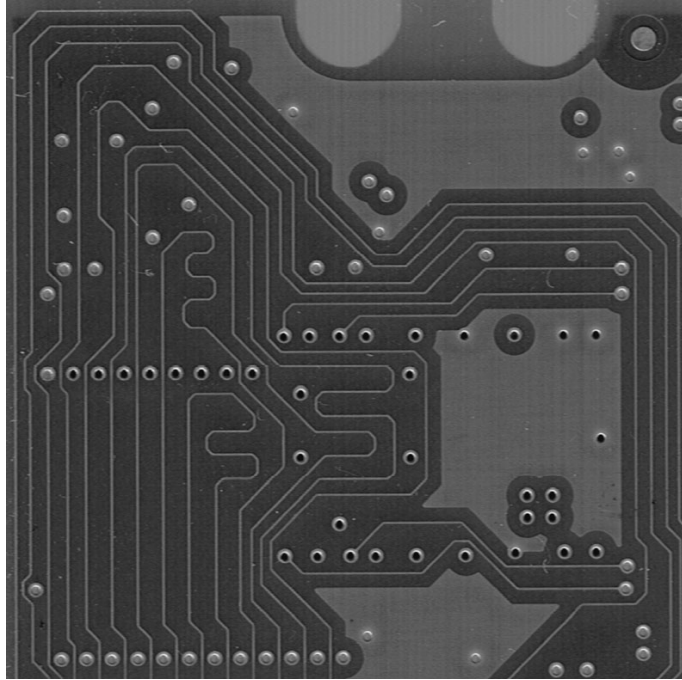


Image $g[x,y]$ (no defect)

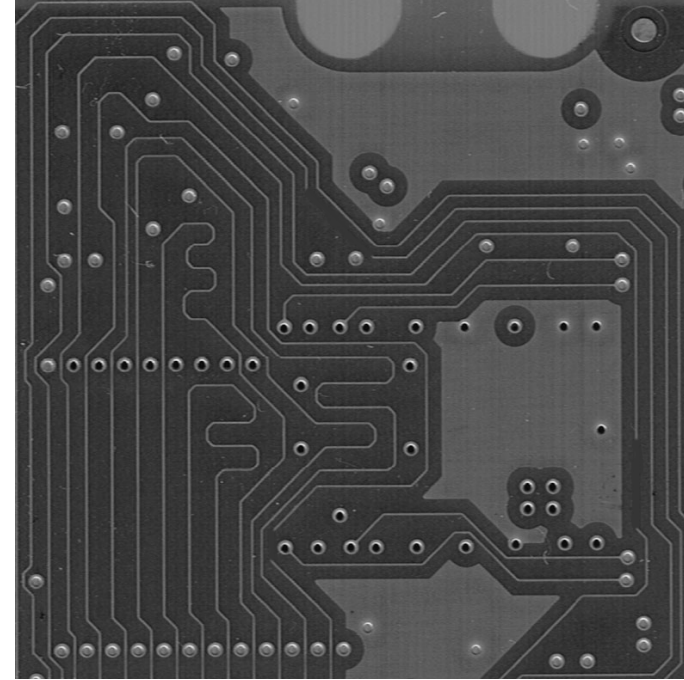
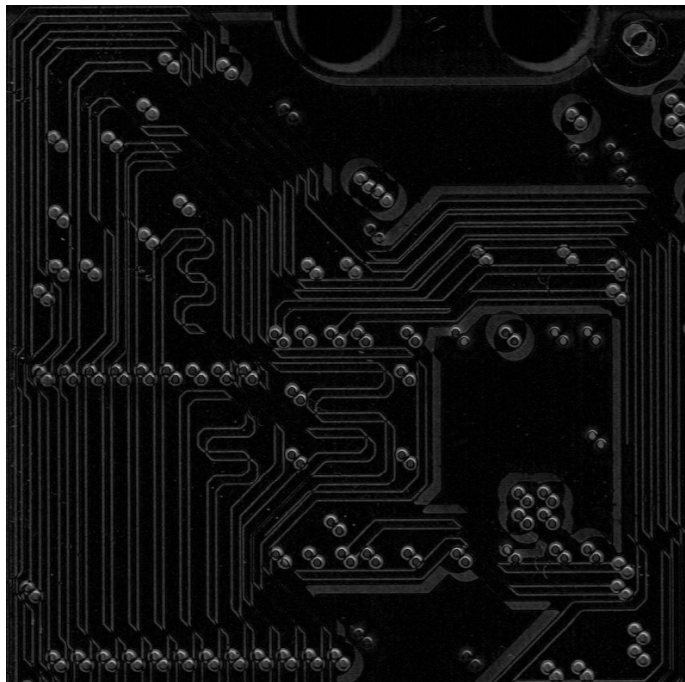


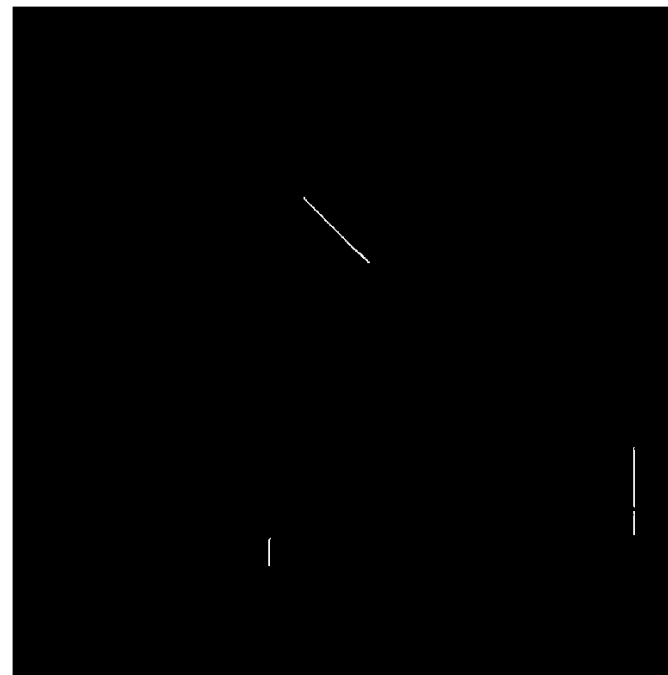
Image $f[x,y]$ (w/ defect)



Absolute difference between two images



$|f-g|$ w/o alignment



$|f-g|$ w/ alignment



Displacement estimation by block matching

Measurement window is compared with a shifted array of pixels in the other image, to determine the best match

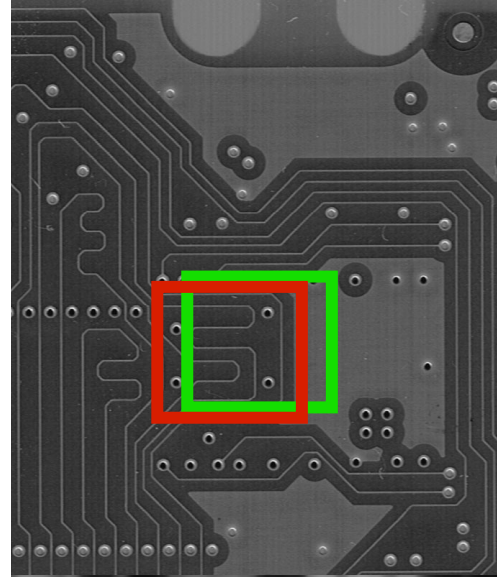


Image $g[x,y]$

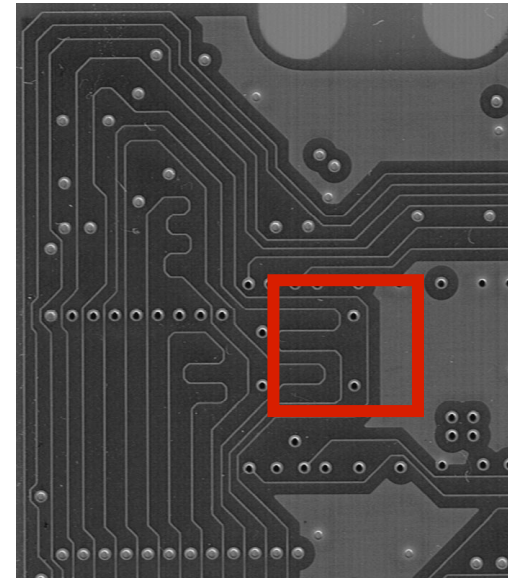


Image $f[x,y]$

Rectangular array of pixels is selected as a measurement window

Displacement estimation by block matching

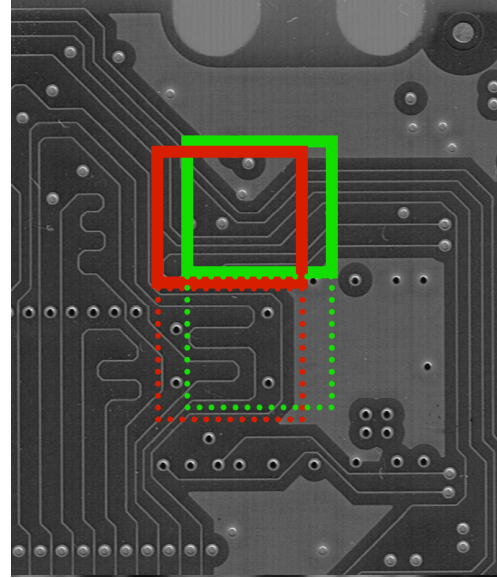


Image $g[x,y]$

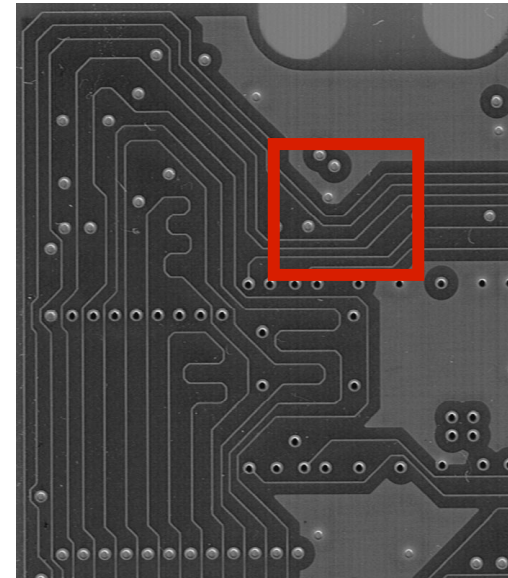


Image $f[x,y]$

. . . process repeated for another
measurement window position.

Integer pixel shifts

Measurement window is compared with a shifted array of pixels in the other image, to determine the best match

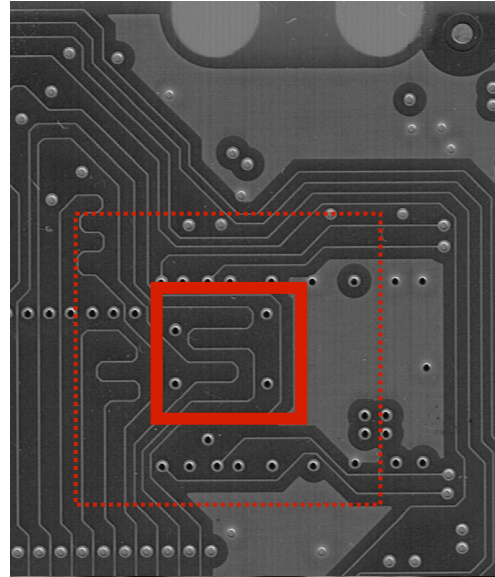


Image $g[x,y]$

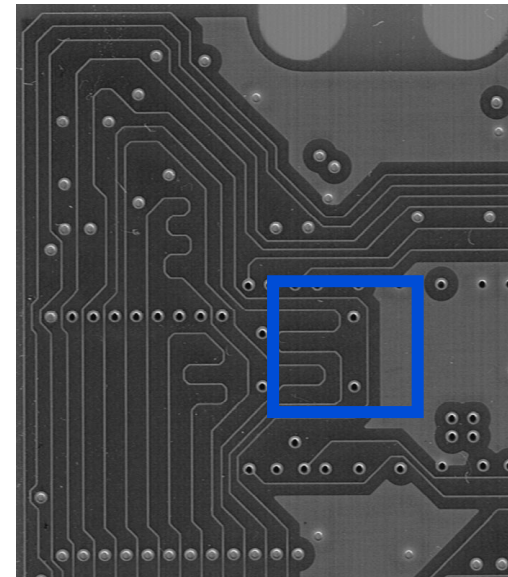
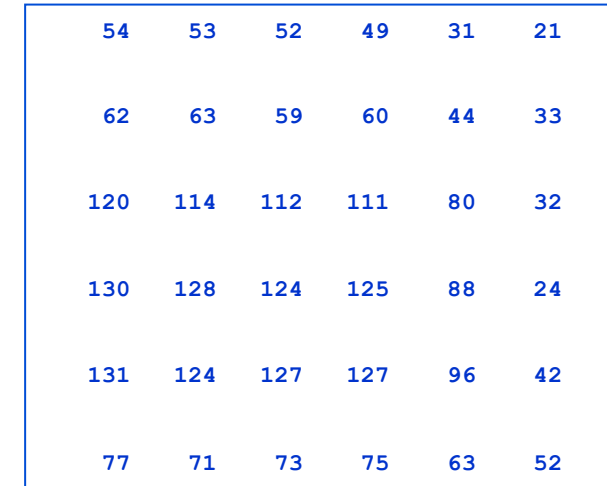
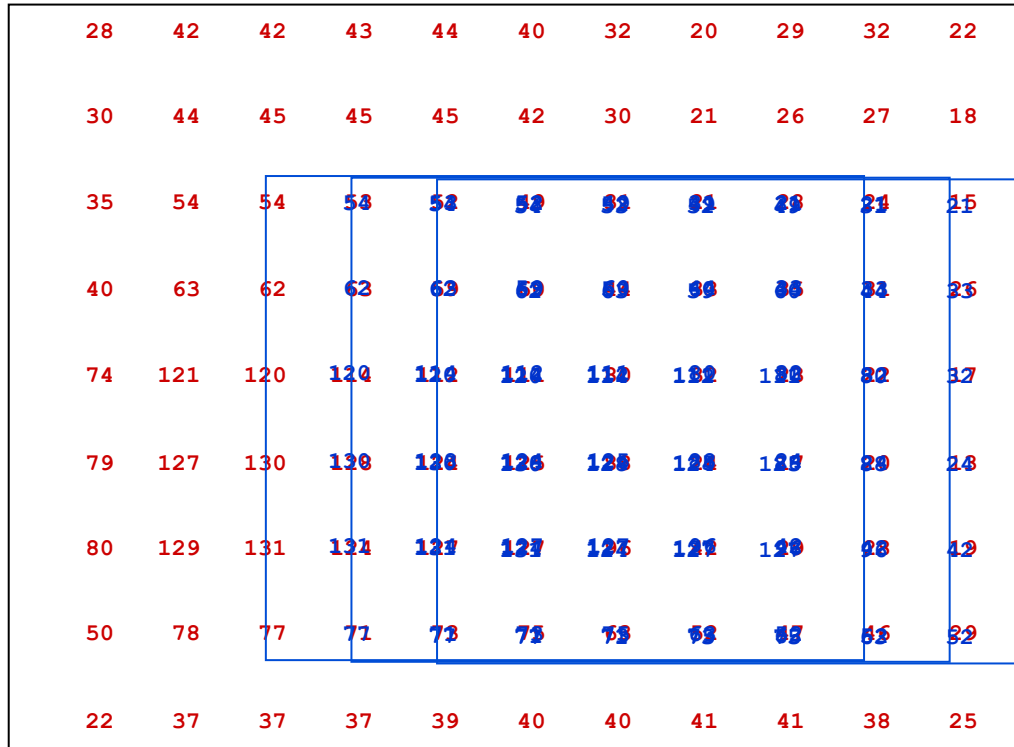


Image $f[x,y]$

Rectangular array of pixels is selected as a measurement window

Integer pixel shifts



Rectangular array of pixels is selected as a measurement window

Measurement window is compared with a shifted array of pixels in the other image, to determine the best match

Error metric

- *Sum of Squared Differences*

Sum all values in measurement window

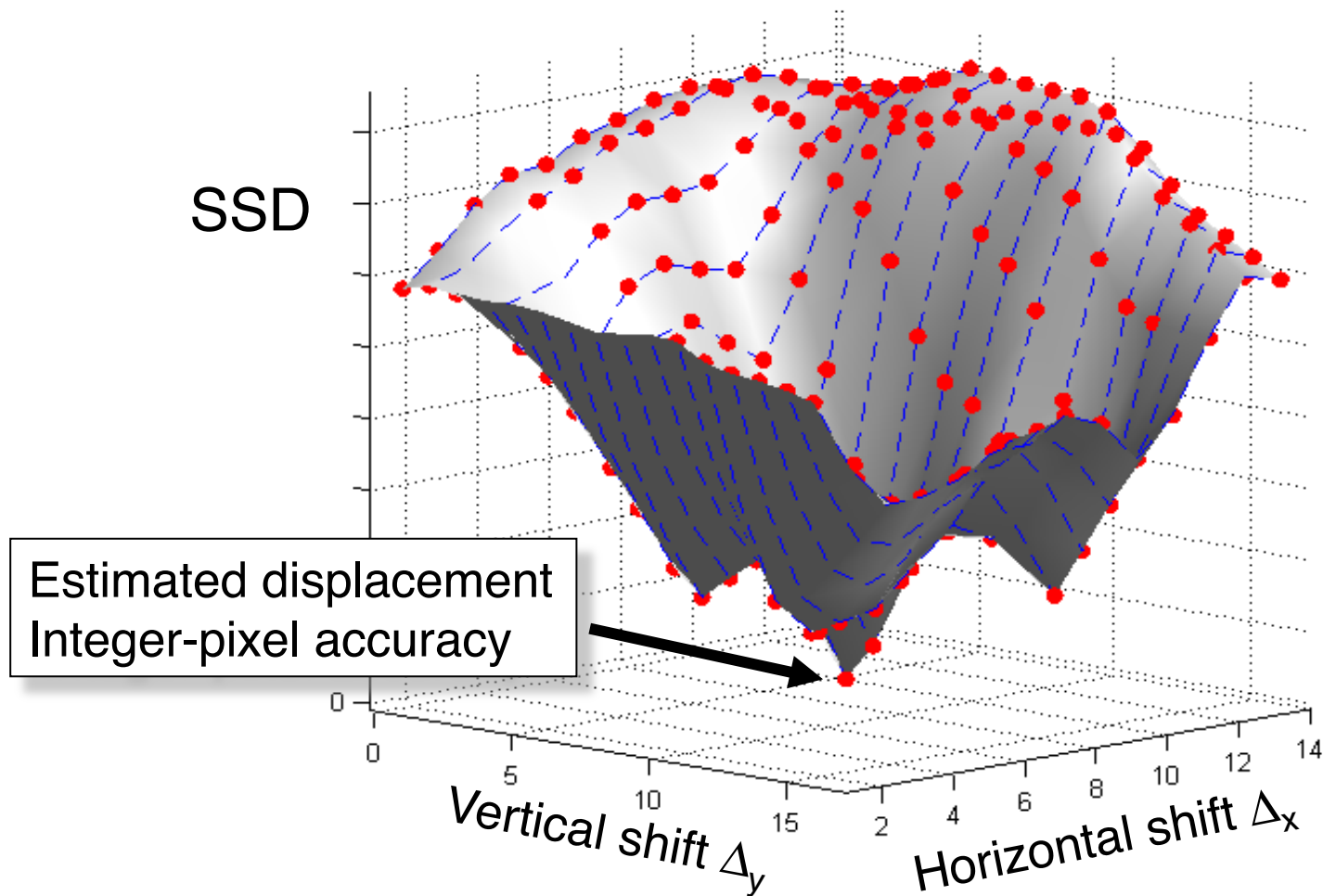
$$SSD[\Delta_x, \Delta_y] = \sum_{[x,y] \in \text{msmnt window}} \left(f[x,y] - g[x + \Delta_x, y + \Delta_y] \right)^2$$

Horizontal displacement

Vertical displacement

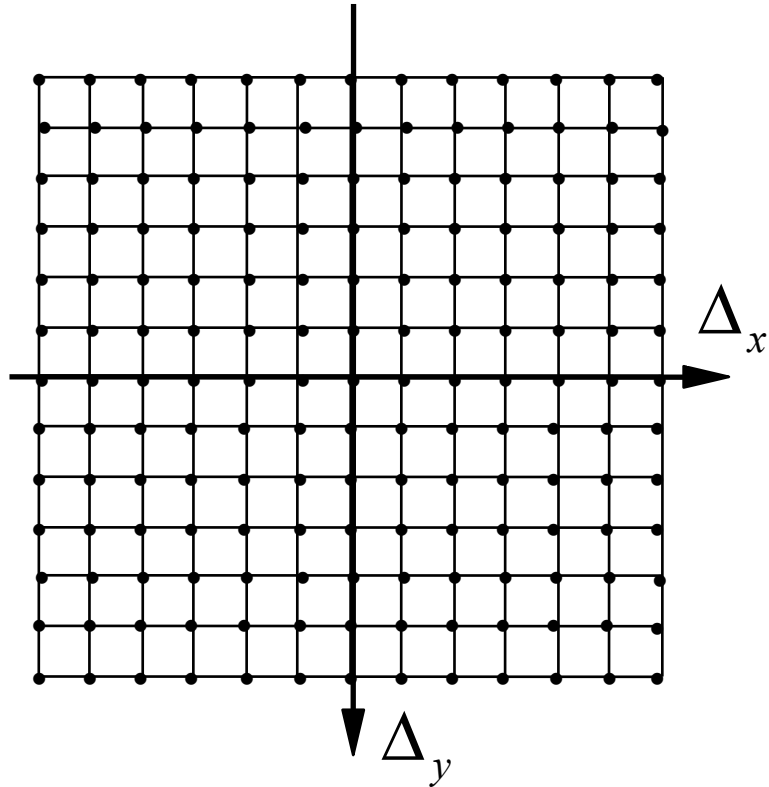
- Alternatives: SAD (*Sum of Absolute Differences*), cross correlation, mutual information . . .
- Robustness against outliers: sum of saturated squared differences, median of squared differences . . .

SSD values resulting from block matching



Block matching: search strategies

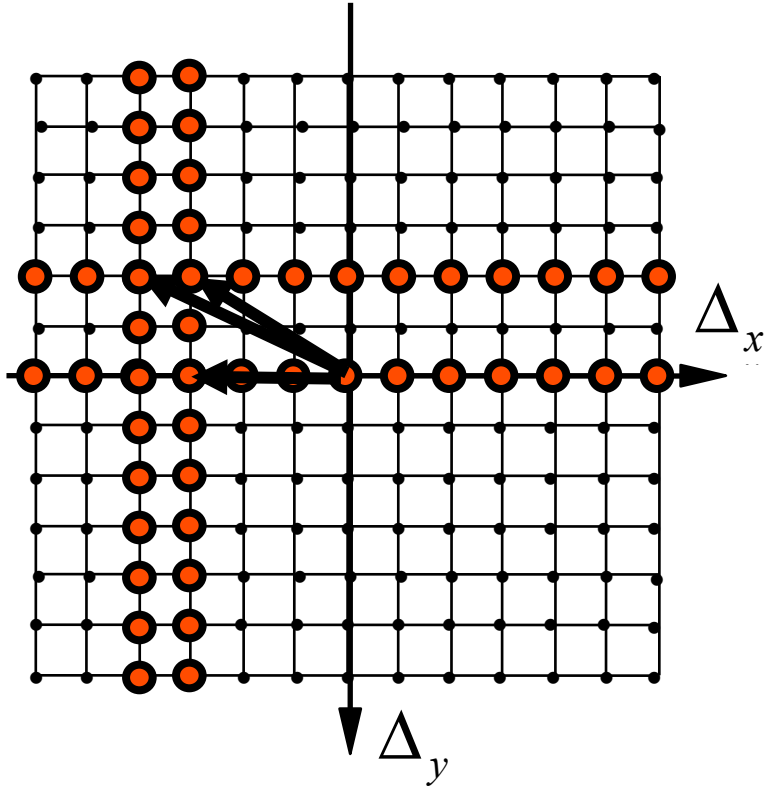
Full search



- All possible displacements within the search range are compared.
- Computationally expensive
- Highly regular, parallelizable

Block matching: search strategies

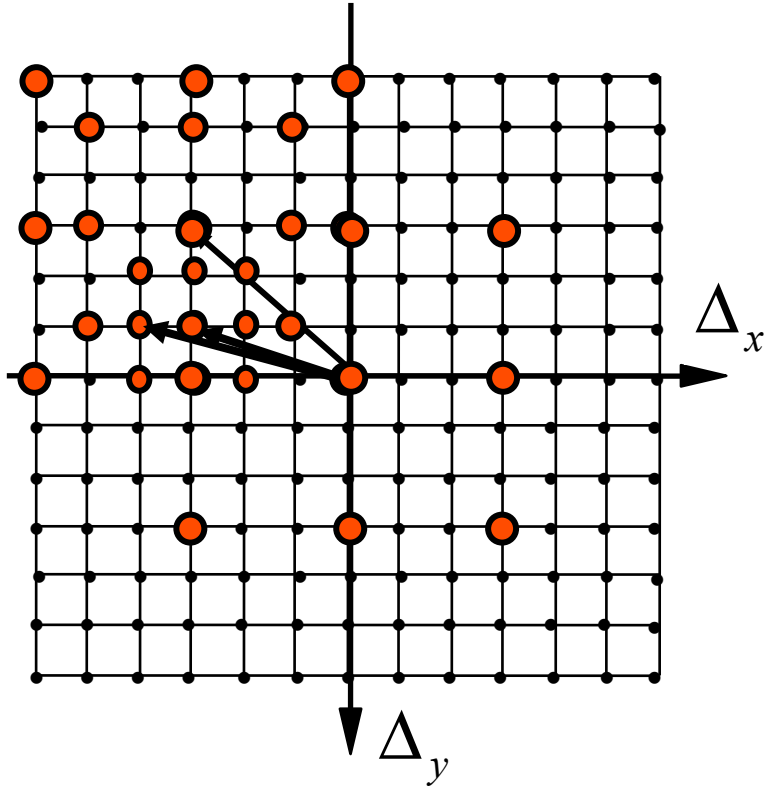
Conjugate direction search



- Alternate search in x and y directions
- Stop when there is no further improvement

Block matching: search strategies

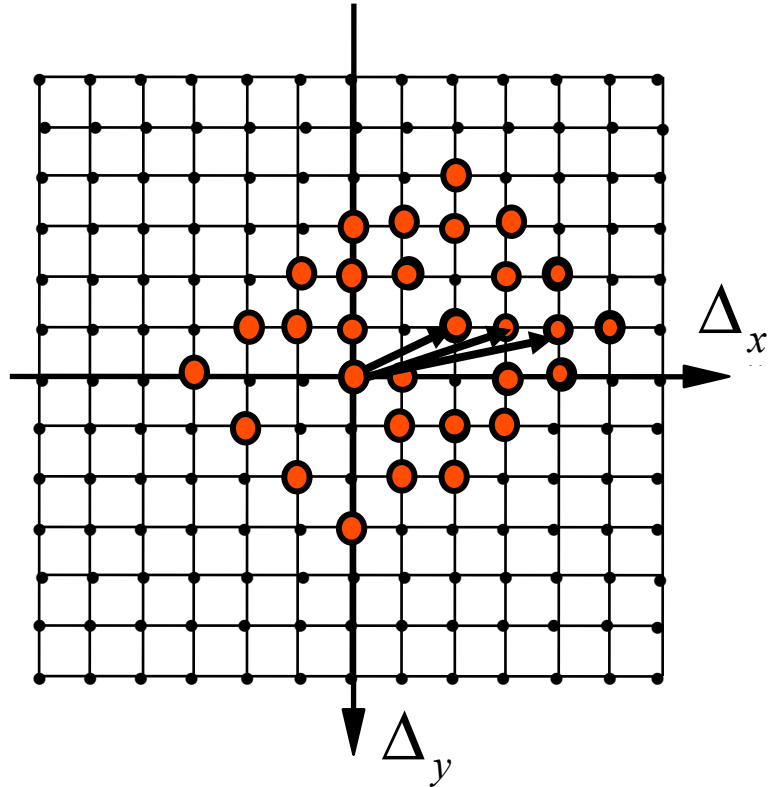
Coarse-to-fine



- Start with coarsely spaced candidate displacements
- Smaller pattern when best match is in the middle
- Stop when desired displacement accuracy is reached

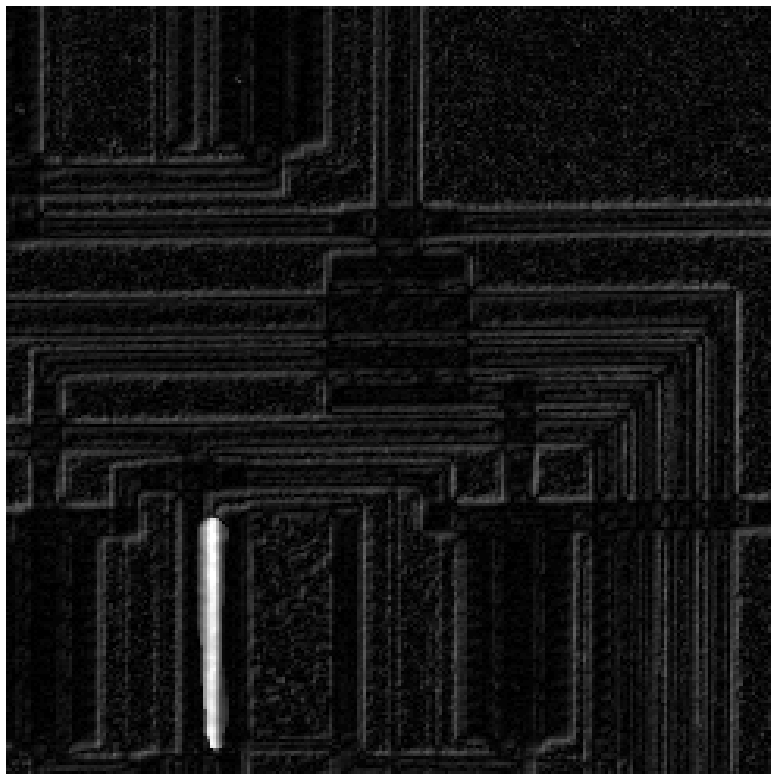
Block matching: search strategies

Diamond search [Li, Zeng, Liou, 1994] [Zhu, Ma, 1997]

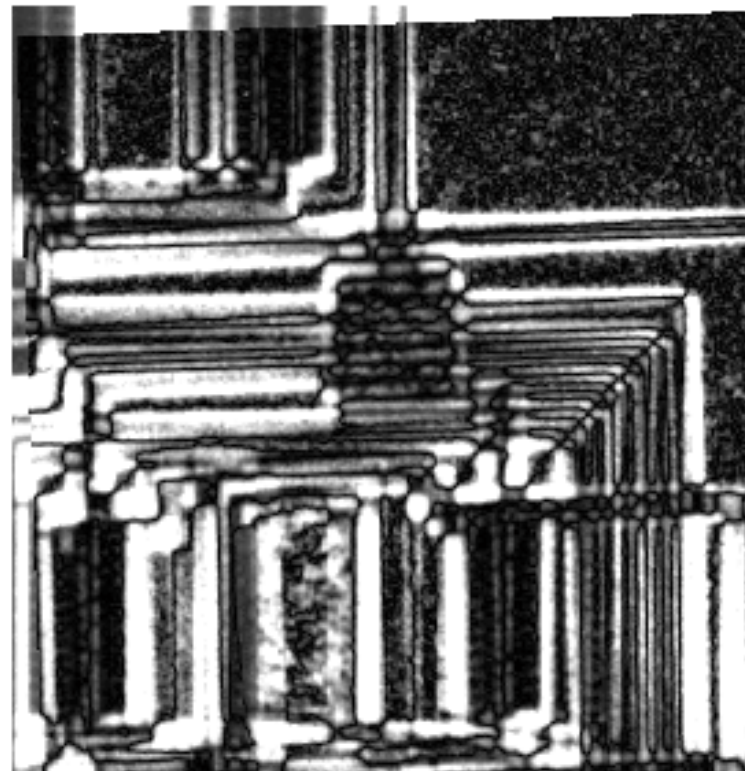


- Start with large diamond pattern at [0,0]
- If best match lies in the center of large diamond, proceed with small diamond
- If best match does not lie in the center of large diamond, center large diamond pattern at new best match

Absolute difference between images

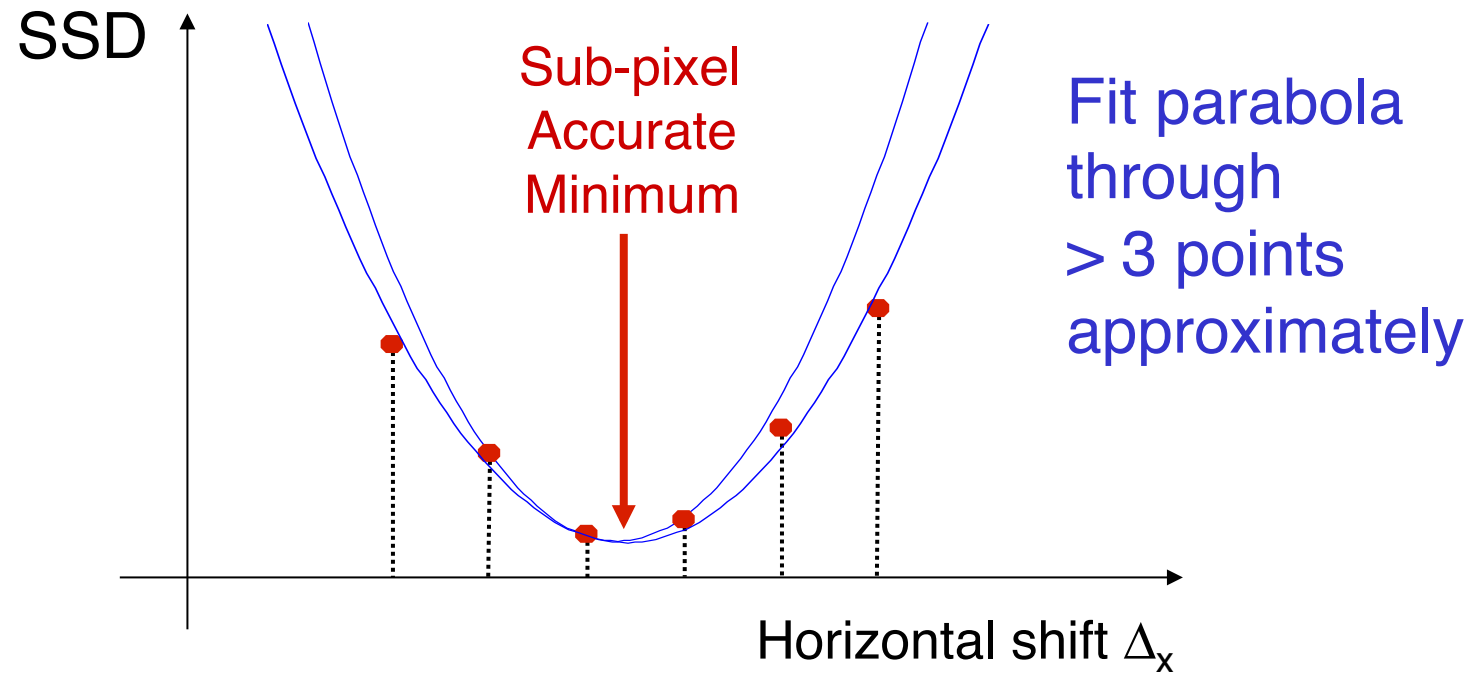


w/ integer-pixel alignment

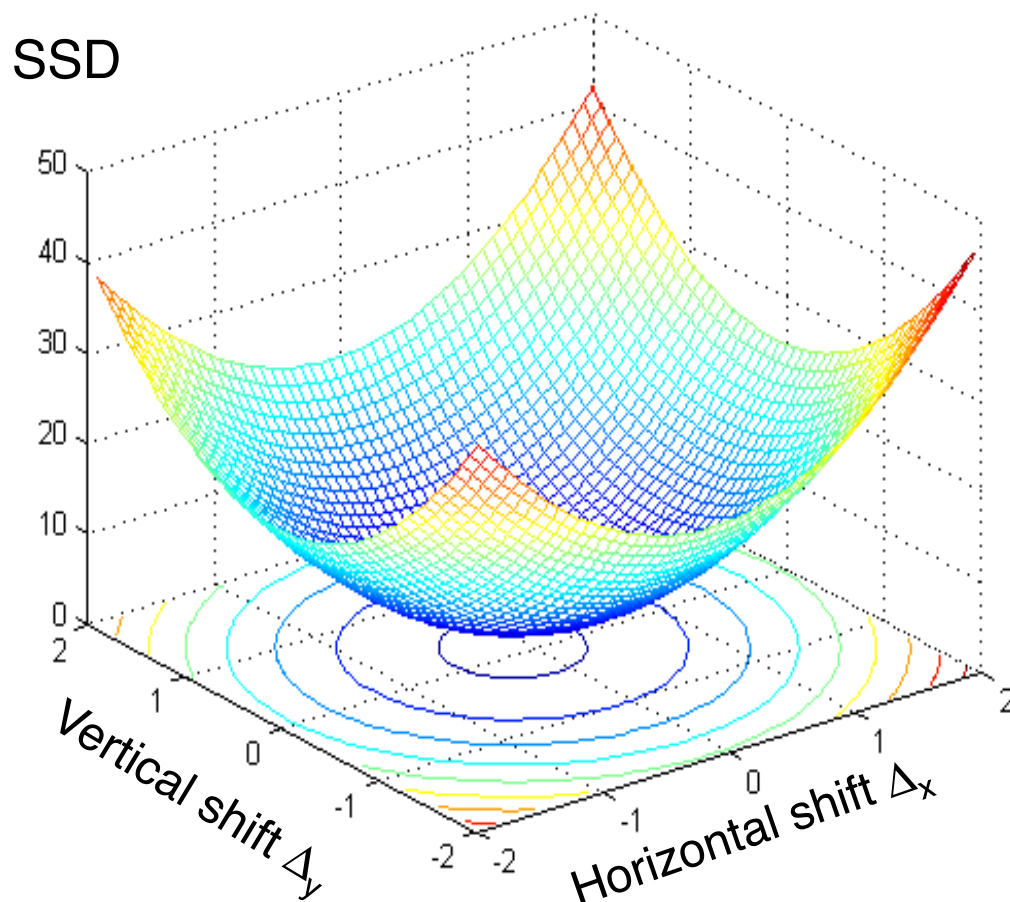


w/o alignment

Interpolation of the SSD Minimum



2-d Interpolation of SSD Minimum



Paraboloid

- Perfect fit through 6 points
- Approximate fit through > 6 points