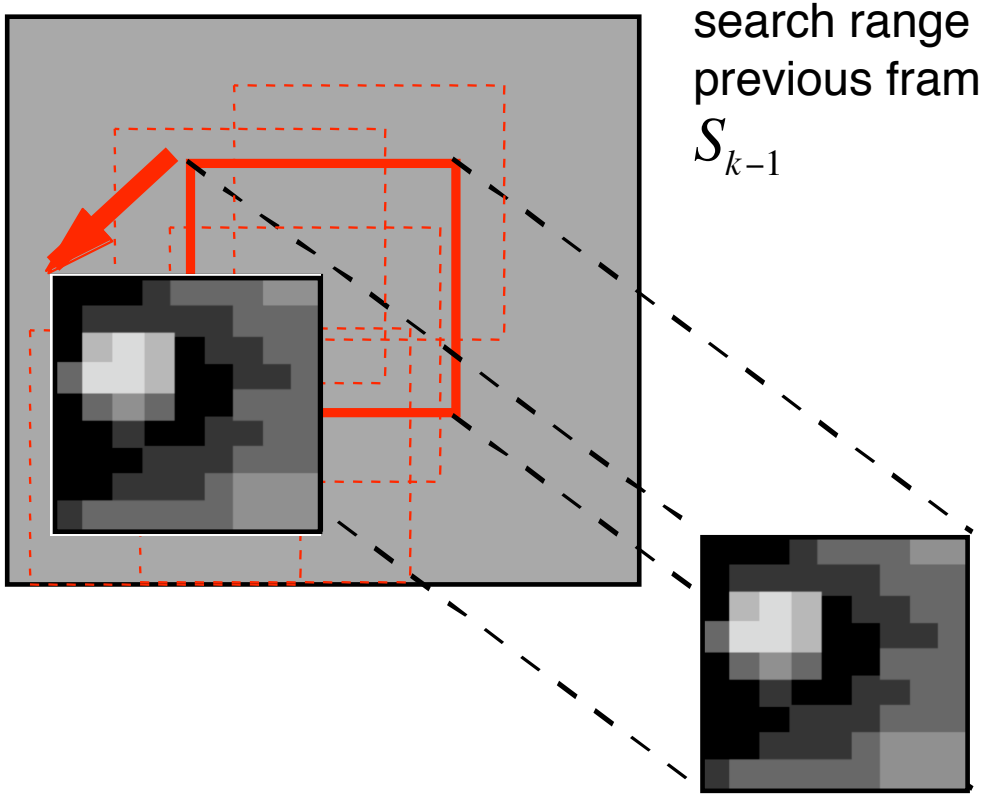
# Motion estimation for video compression

- Blockmatching
- Search strategies for block matching
- Block comparison speedups
- Hierarchical blockmatching
- Sub-pixel accuracy

# Block-matching algorithm

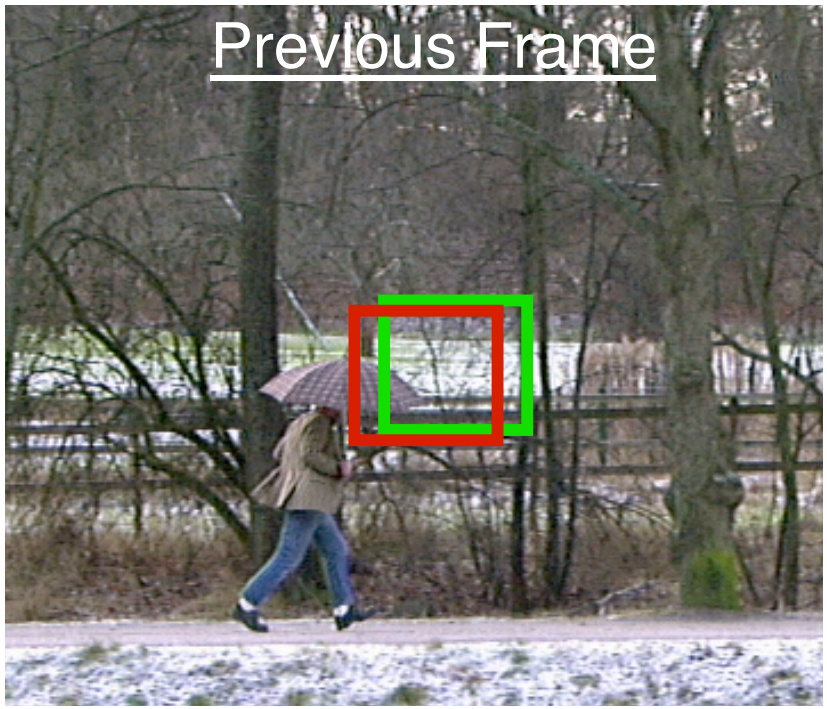


search range in previous frame $S_{k-1}$

block of current frame $S_k$

- Subdivide current frame into blocks.
- Find one displacement vector for each block.
- Within a search range, find a "best match" that minimizes an error measure.
- Intelligent search strategies can reduce computation.

# Block-matching algorithm

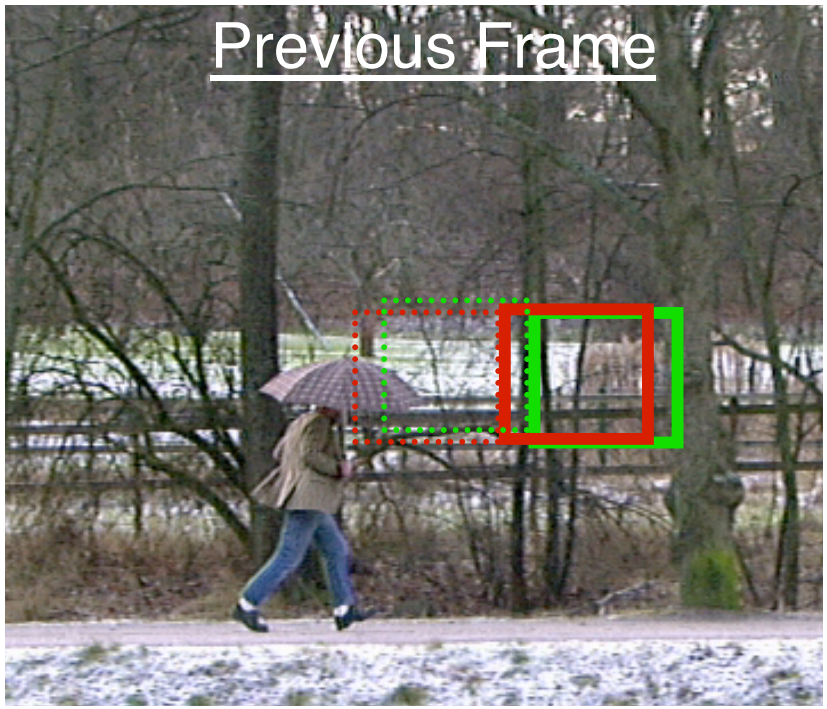




Measurement window is compared with a shifted block of pixels in the other image, to determine the best match

Block of pixels is selected as a measurement window

# Block-matching algorithm

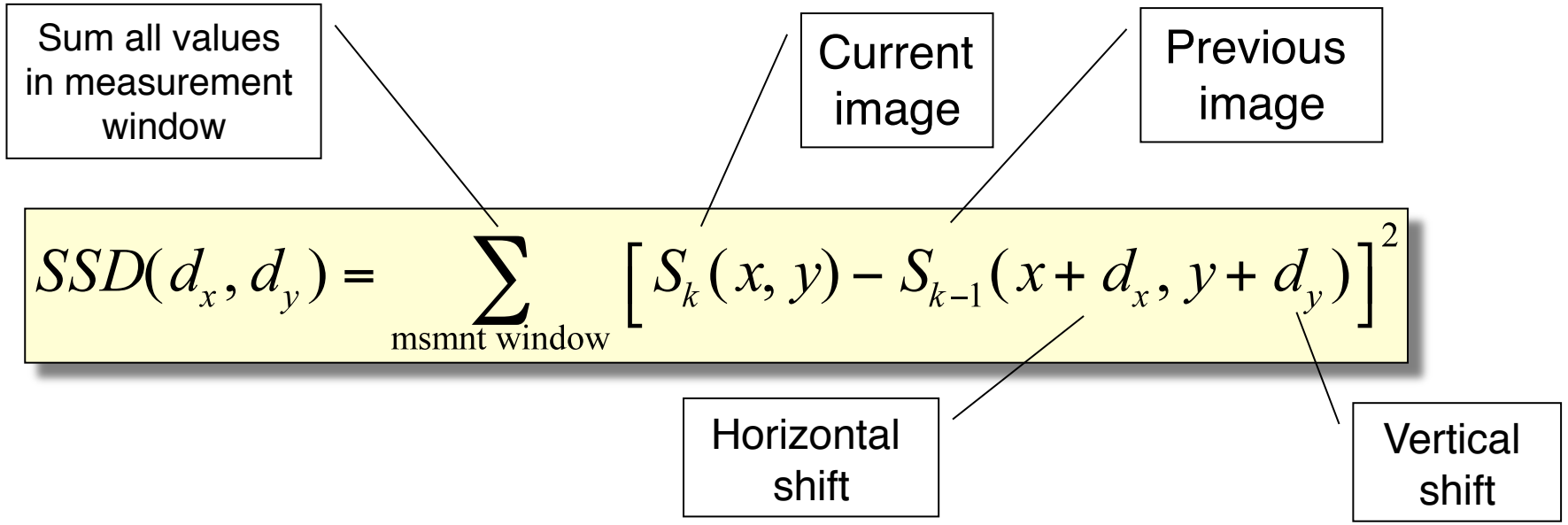




. . . process repeated for another block.

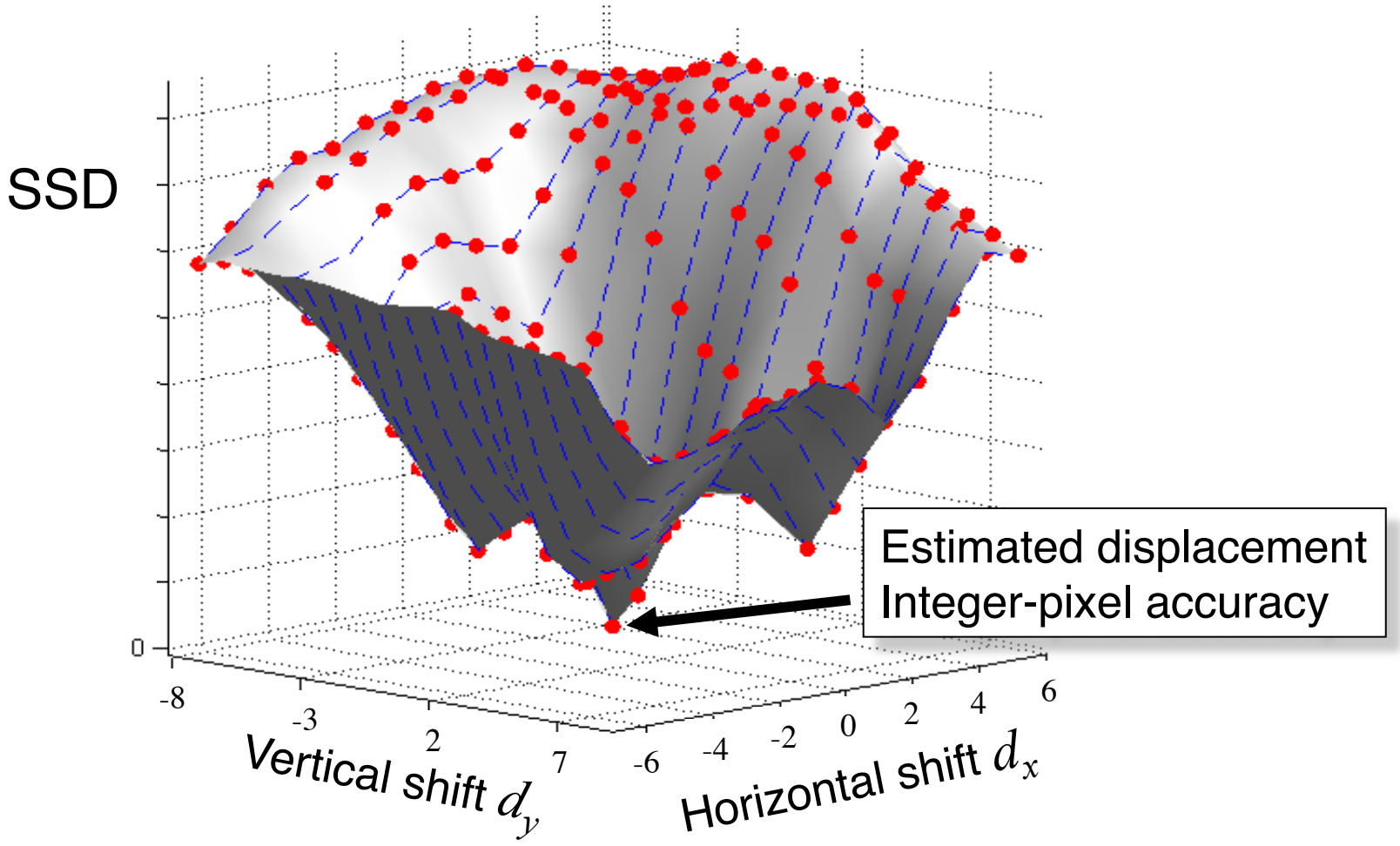
# Blockmatching: Matching Criterion

- *Sum of Squared Differences* to determine similarity




- Alternative matching criteria: SAD (*Sum of Absolute Differences*), cross correlation, . . .
- How about sub-pixel shifts?

# SSD Values Resulting from Blockmatching

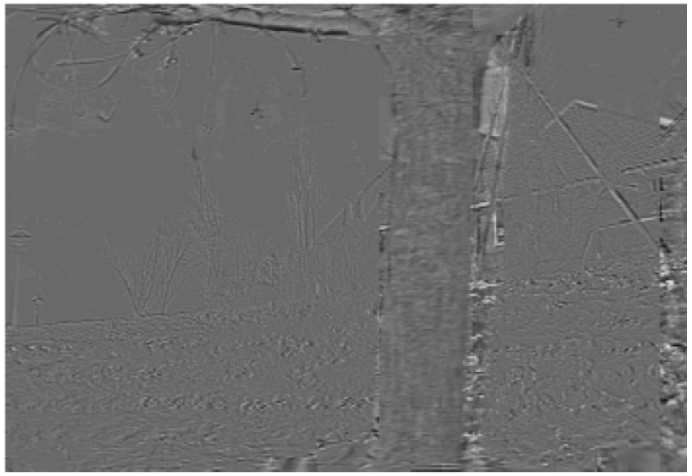



# Motion-compensated prediction: example

Previous frame

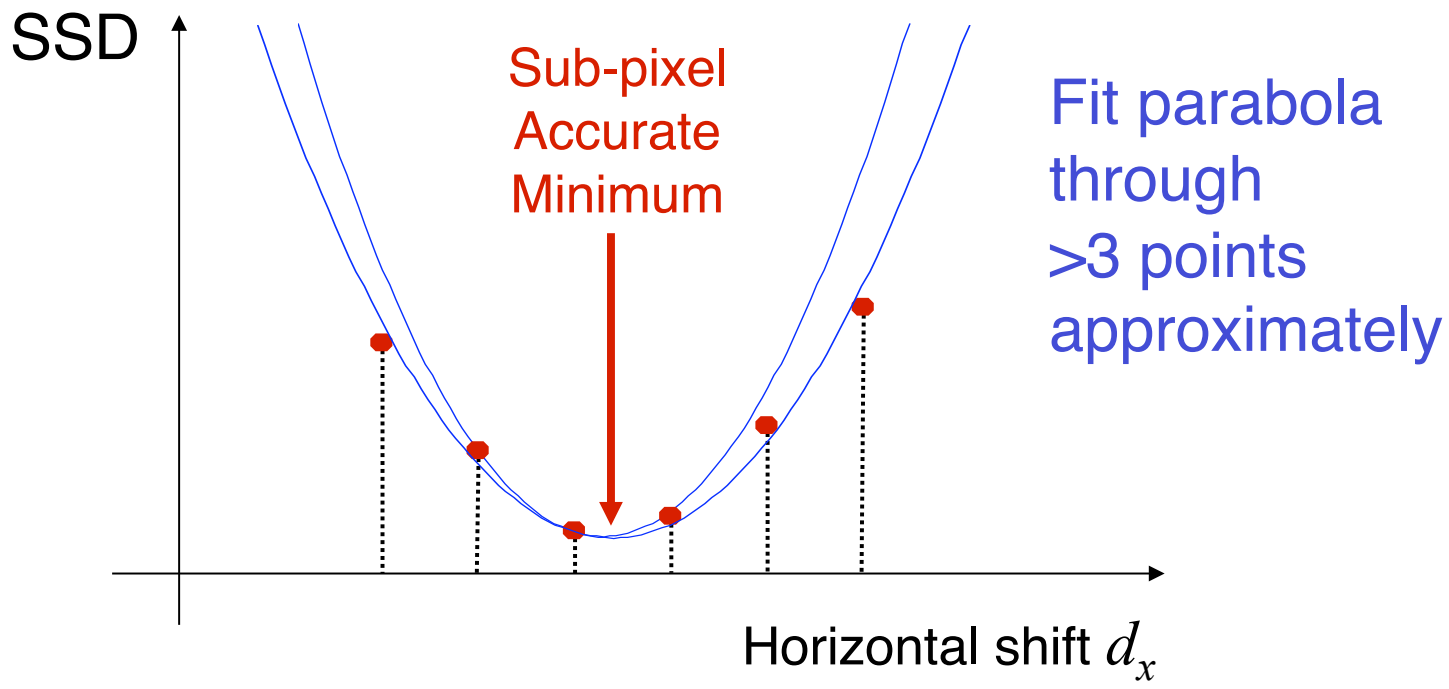
Current frame

Prediction with
displacement vectors



Motion-compensated
Prediction error

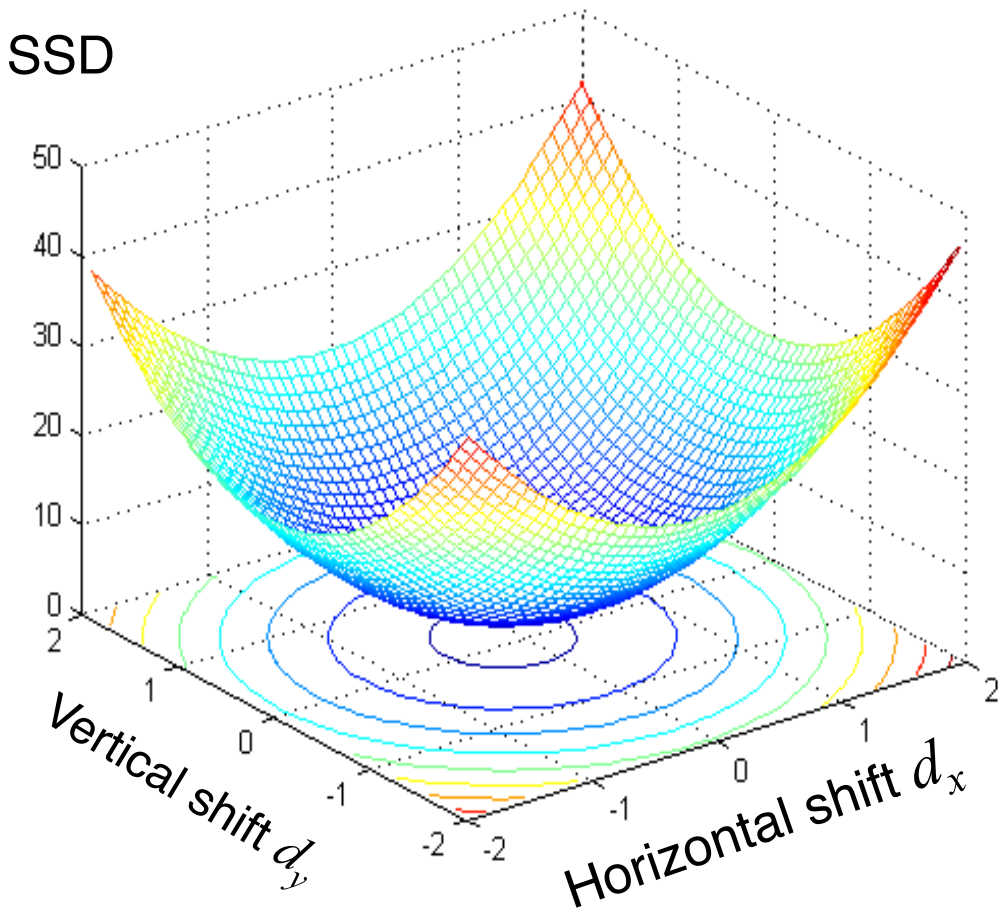
# Interpolation of the SSD Minimum




# 2-d Interpolation of SSD Minimum

Paraboloid

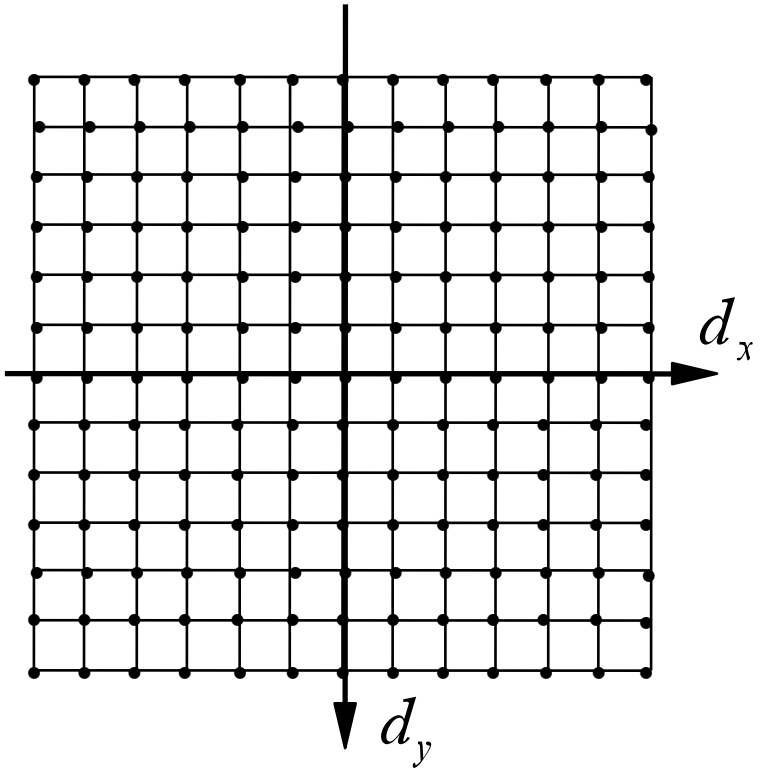
- Perfect fit through 6 points
- Approximate fit through >6 points




# Blockmatching: search strategies I

## Full search

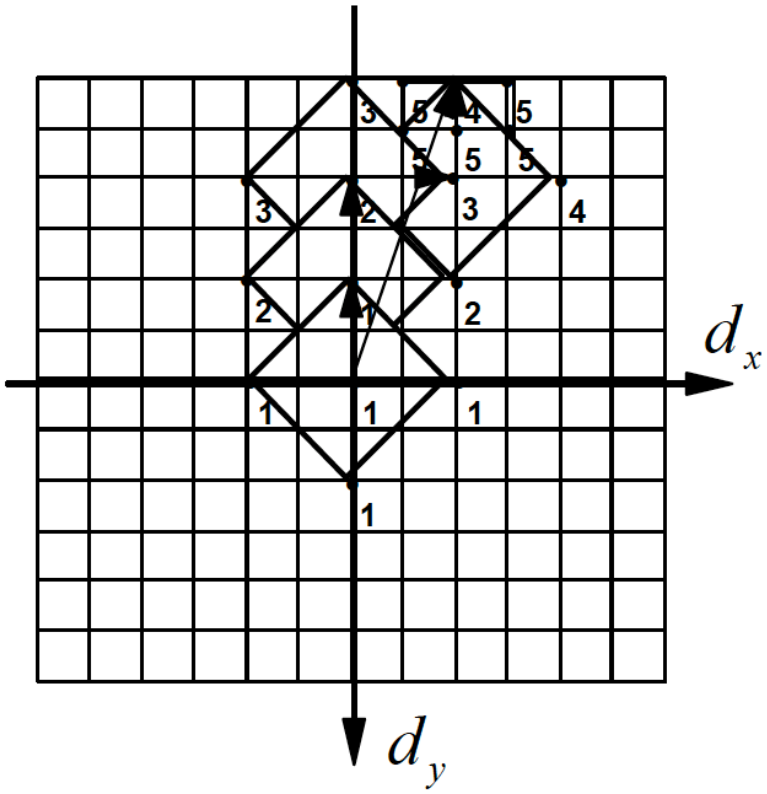
- All possible displacements within the search range are compared.
- Computationally expensive
- Highly regular, parallelizable




# Blockmatching: search strategies II

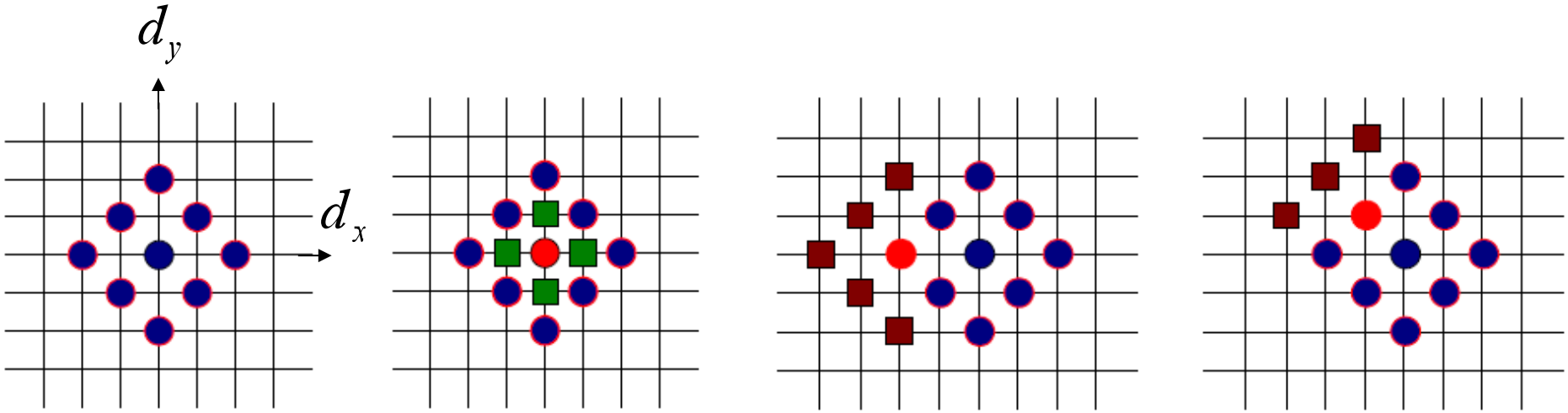
## 2D logarithmic search [Jain + Jain, 1981]

- Iterative comparison of error measure values at 5 neighboring points
- Logarithmic refinement of the search pattern if
  - best match is in the center of the 5-point pattern
  - center of search pattern touches the border of the search range




# Blockmatching: search strategies III

## **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

# Blockmatching: search strategies IV

*Most search strategies can be further accelerated by . . .*

- Predictive motion search
  - Use median of motion vectors in causal neighborhood as starting point for search.
  - Additionally test zero-vector as a starting point
- Early termination
  - Interrupt summation to calculate SSD or SAD, if value grows too quickly (relative to previous best match)
  - Stop search, if match is “good enough” (SSD, SAD < threshold)

# Block comparison speed-ups

- Triangle and Cauchy-Schwarz inequalities for SAD and SSE

$$\sum_{\text{block}} \left| S_k - S_{k-1} \right| \geq \left| \sum_{\text{block}} S_k - S_{k-1} \right| = \left| \sum_{\text{block}} S_k - \sum_{\text{block}} S_{k-1} \right|$$

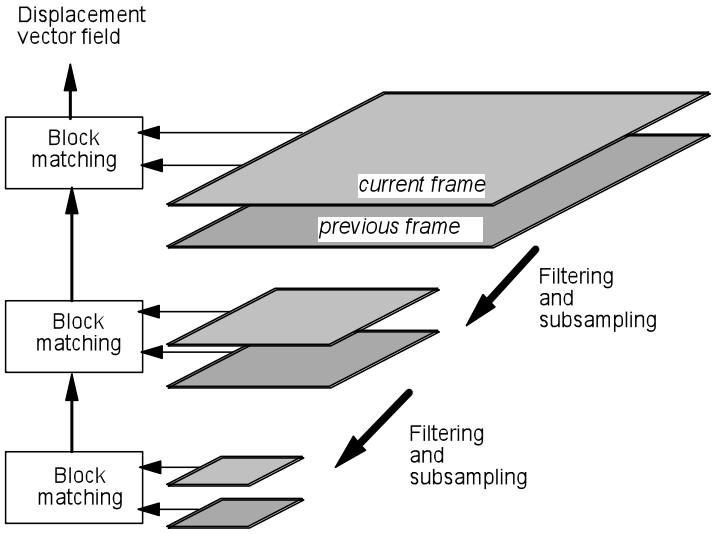
$$\sum_{\text{block}} \left( S_k - S_{k-1} \right)^2 \geq \frac{1}{N} \left( \sum_{\text{block}} S_k - S_{k-1} \right)^2 = \frac{1}{N} \left( \sum_{\text{block}} S_k - \sum_{\text{block}} S_{k-1} \right)^2$$

number of terms in sum

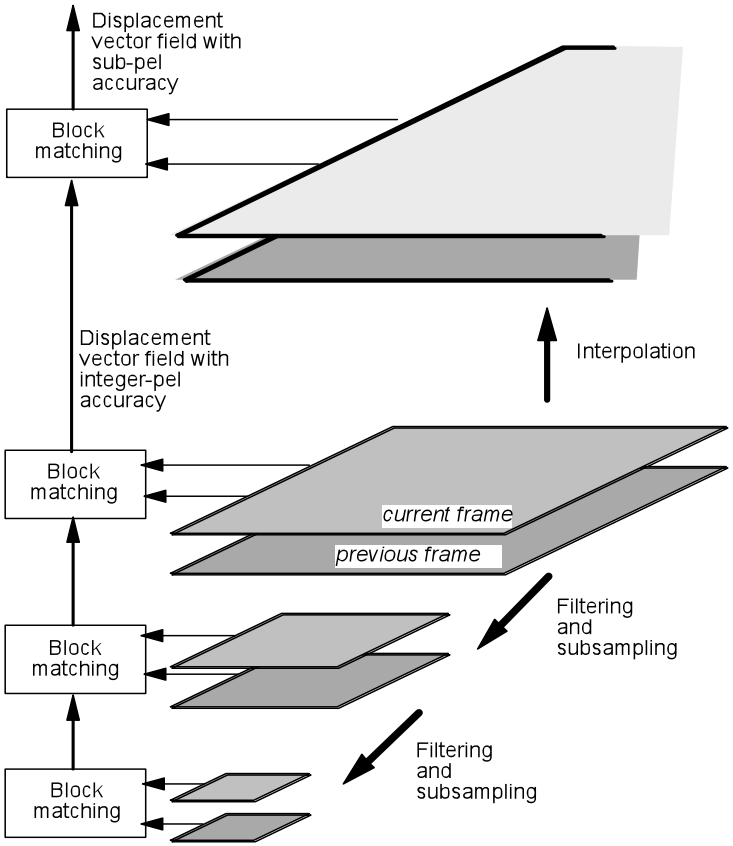
- Strategy:
  - Compute partial sums for blocks in current and previous frame
  - Compare blocks based on partial sums
  - Omit full block comparison, if partial sums indicate worse error measure than previous best result
- Performance: > 20x speed-up of full search block matching reported by employing *[Lin + Tai, IEEE Tr. Commun., May 97]*
  - Sum over 16x16 block
  - Row wise block projection
  - Column wise block projection

# Hierarchical blockmatching

## Integer-pixel accuracy

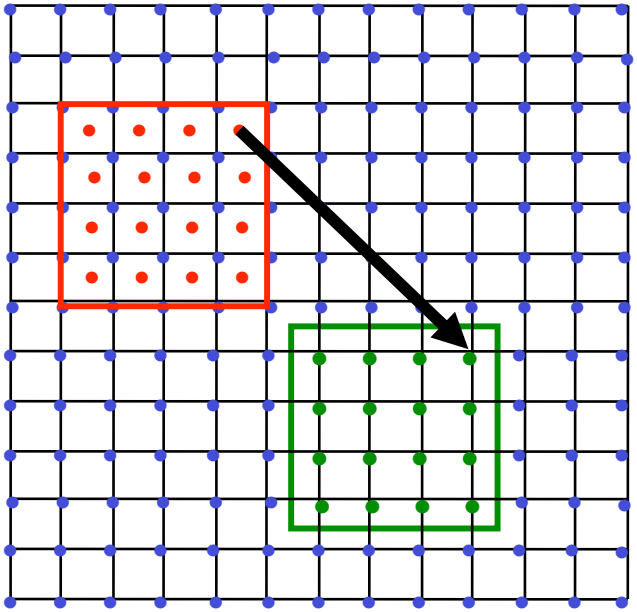



## Extension to sub-pixel accuracy



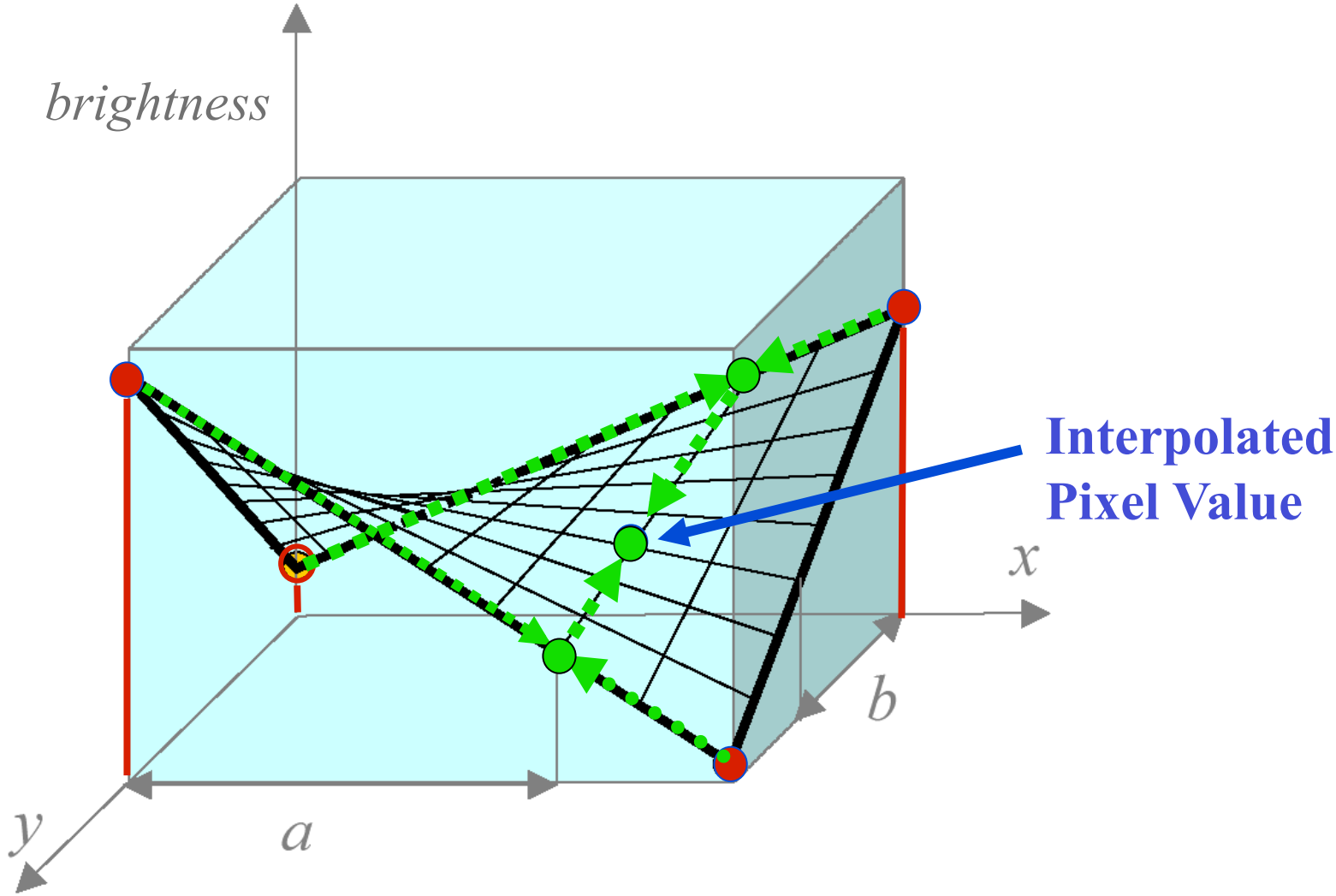

# Sub-pixel accuracy

- Interpolate pixel raster of the reference image to desired sub-pixel accuracy (typically by bi-linear interpolation)
- Straightforward extension of displacement vector search to fractional accuracy
- Example: half-pixel accurate displacements



$$\begin{pmatrix} d_x \\ d_y \end{pmatrix} = \begin{pmatrix} 4.5 \\ 4.5 \end{pmatrix}$$

# Bi-linear Interpolation




# Reading

- J. R. Jain, A. K. Jain, “Displacement Measurement and Its Application in Interframe Image Coding,” IEEE Trans. Communications, vol. COM-29, no. 12, pp. 1799-1808, Dec. 1981.
- Y.-C. Lin, S.-C. Tai, “Fast Full-Search Block-Matching Algorithm for Motion-Compensated Video Compression,” IEEE Trans. Communications, vol. 45, no. 5, pp. 527-531, May 1997.