Binocular Stereo Vision

Properties of human stereo processing

Marr-Poggio-Grimson multi-resolution stereo algorithm

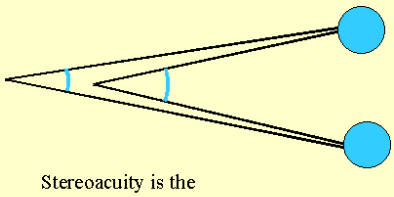
CS332 Visual Processing
Department of Computer Science
Wellesley College

Properties of human stereo processing

Use features for stereo matching whose position and disparity can be measured *very precisely*

Stereoacuity is only a few seconds of visual angle

difference in depth ≈ 0.01 cm
at a viewing distance of 30 cm



Stereoacuity is the difference between the two angles

Properties of human stereo processing

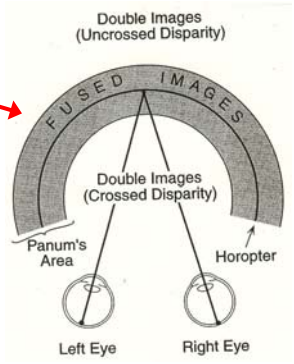
Matching features must appear *similar* in the left and right images

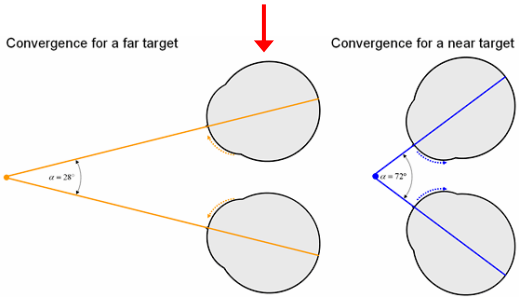
For example, we can't fuse a left stereo image with a negative of the right image…

Properties of human stereo processing

Only "fuse" objects within a limited range of depth around the fixation distance

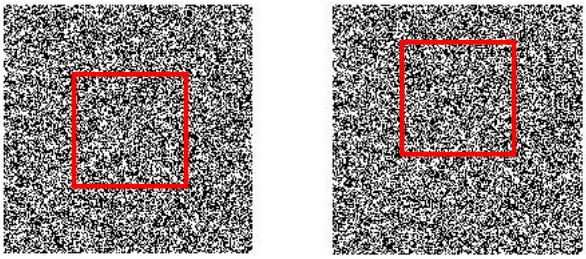
Vergence eye movements are needed to fuse objects over larger range of depths





Properties of human stereo vision

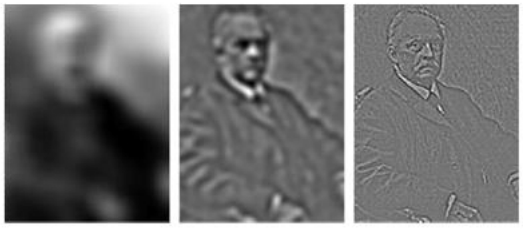
We can only tolerate small amounts of *vertical disparity* at a single eye position



Vertical eye movements are needed to handle large vertical disparities

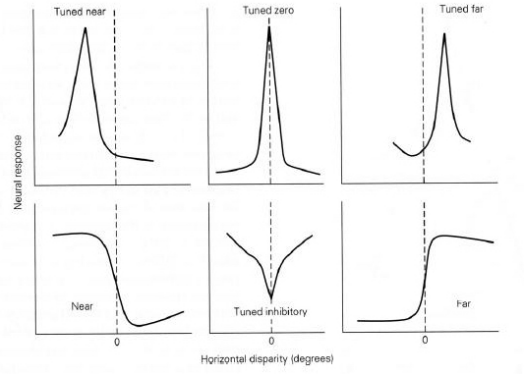
Properties of human stereo processing

In the early stages of visual processing, the image is analyzed at *multiple spatial scales…*



Stereo information at multiple scales can be processed independently

Neural mechanisms for stereo processing



zero disparity: at fixation distance
near: in front of point of fixation
far: behind point of fixation

G. Poggio & colleagues:

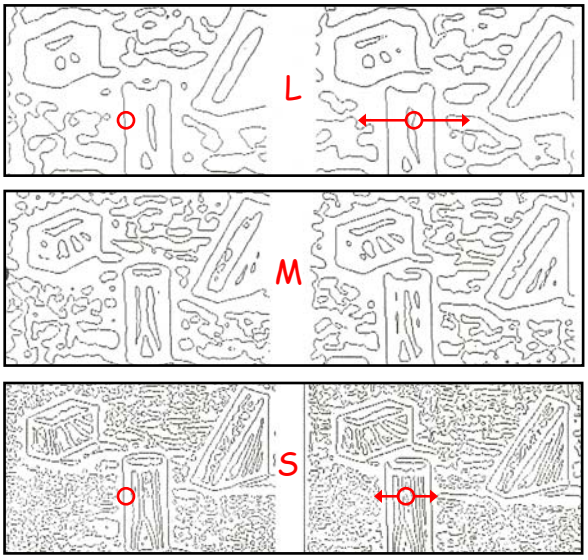
complex cells in area V1 of primate visual cortex are selective for stereo disparity

neurons that are selective for a larger disparity range have larger receptive fields

In summary, some key points…

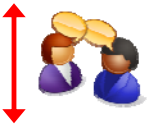
- Image features used for matching:
  simple, precise locations, multiple scales, similar between left/right images
- At single fixation position, match features over a limited range of horizontal & vertical disparity
- Eye movements used to match features over larger range of disparity
- Neural mechanisms selective for particular ranges of stereo disparity

Matching features for the MPG stereo algorithm

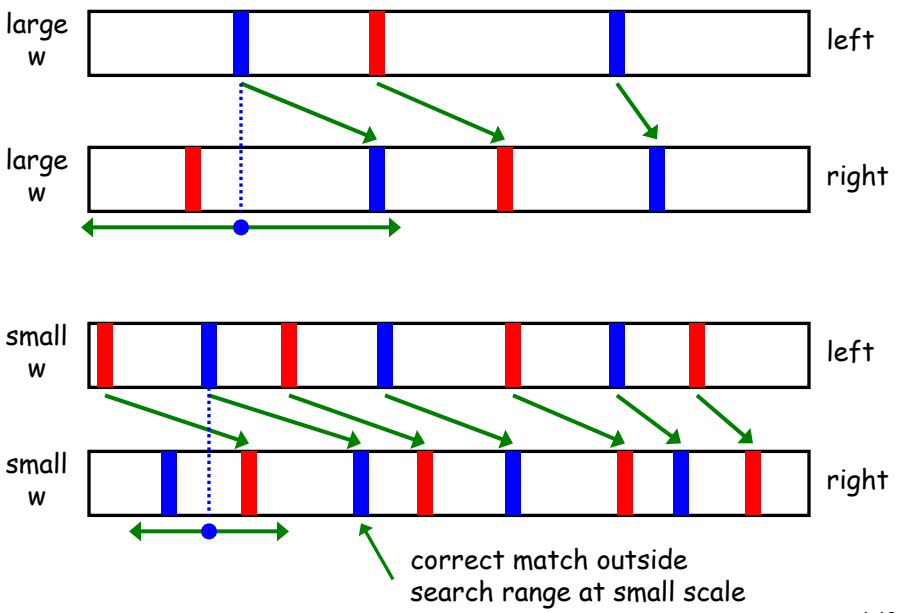


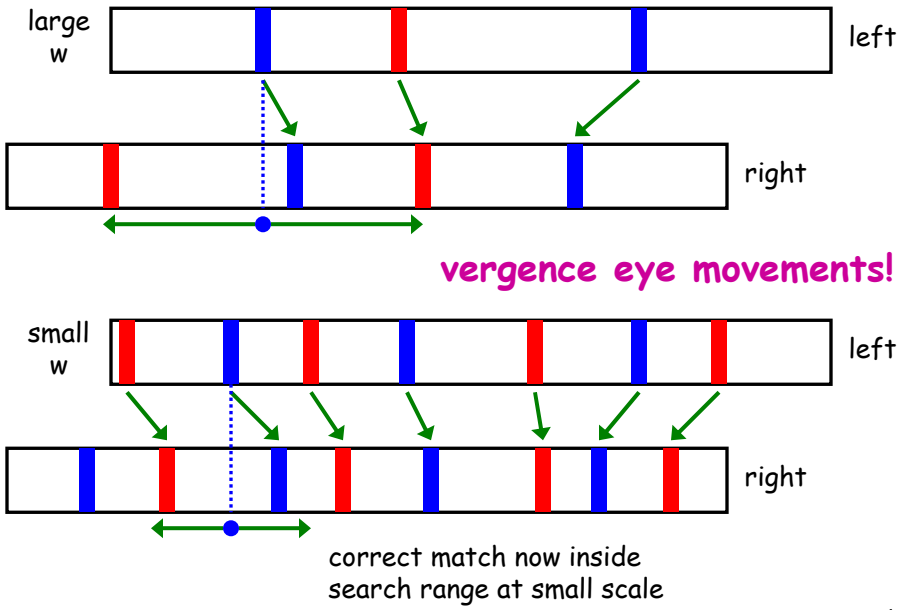
zero-crossings of convolutions with $\nabla^2 G$ operators of different size

rough disparities over large range

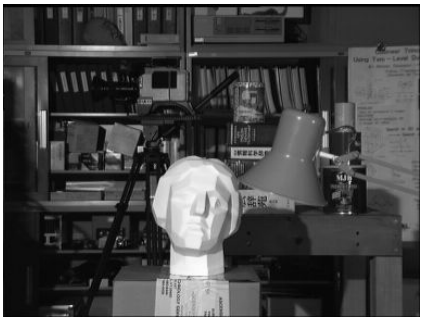


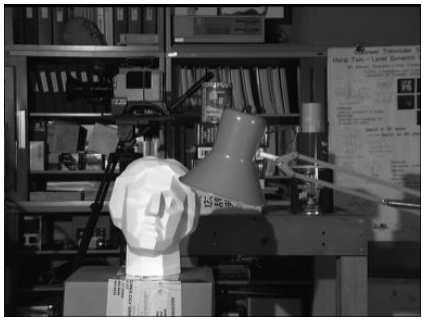
accurate disparities over small range



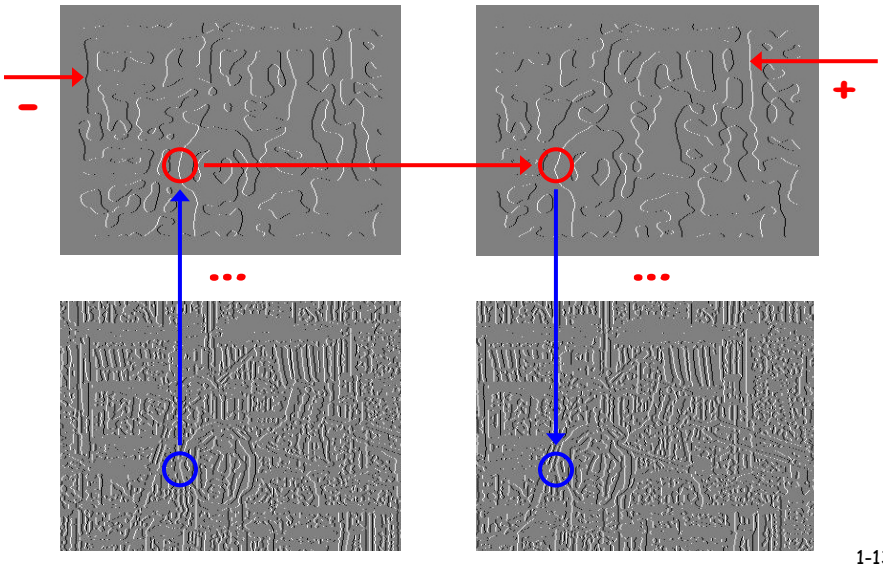


Stereo images (Tsukuba, CMU)





Zero-crossings for stereo matching



Simplified MPG algorithm, Part 1

To determine initial correspondence:

(1) Find zero-crossings using a $\nabla^2 G$ operator with central positive width w

(2) For each horizontal slice:

(2.1) Find the nearest neighbors in the right image for each zero-crossing fragment in the left image

(2.2) Fine the nearest neighbors in the left image for each zero-crossing fragment in the right image

(2.3) For each pair of zero-crossing fragments that are closest neighbors of one another, let the right fragment be separated by $\delta_{initial}$ from the left. Determine whether $\delta_{initial}$ is within the matching tolerance, m. If so, consider the zero-crossing fragments matched with disparity $\delta_{initial}$

$$m = w/2$$

Simplified MPG algorithm, Part 2

To determine final correspondence:

(1) Find zero-crossings using a $\nabla^2 G$ operator with reduced width w/2

(2) For each horizontal slice:

(2.1) For each zero-crossing in the left image:

(2.1.1) Determine the nearest zero-crossing fragment in the left image that matched when the $\nabla^2 G$ operator width was w

(2.1.2) Offset the zero-crossing fragment by a distance $\delta_{initial}$, the disparity of the nearest matching zero-crossing fragment found at the lower resolution with operator width w

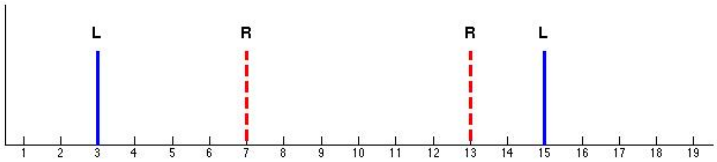
(2.2) Find the nearest neighbors in the right image for each zero-crossing fragment in the left image

(2.3) Fine the nearest neighbors in the left image for each zero-crossing fragment in the right image

(2.4) For each pair of zero-crossing fragments that are closest neighbors of one another, let the right fragment be separated by δ_{new} from the left. Determine whether δ_{new} is within the reduced matching tolerance, m/2. If so, consider the zero-crossing fragments matched with disparity $\delta_{final} = \delta_{new} + \delta_{initial}$

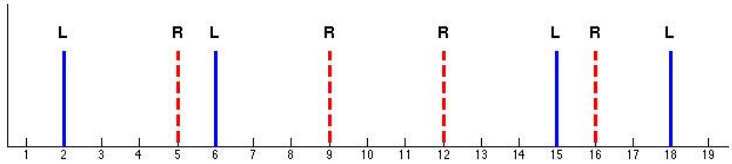
Coarse-scale zero-crossings:

w = 8
m = 4



Use coarse-scale disparities to guide fine-scale matching:

w = 4
m = 2



Ignore coarse-scale disparities:

w = 4
m = 2