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
Properties of human stereo processing

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

For example, a left stereo image cannot be fused 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

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

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

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 convolution with $\nabla^2 G$ operators of different size
- Rough disparities over large range
- Accurate disparities over small range

Correct match outside search range at small scale
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) Find 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 $\delta_{\text{initial}}$ from the left. Determine whether $\delta_{\text{initial}}$ is within the matching tolerance, $m$. If so, consider the zero-crossing fragments matched with disparity $\delta_{\text{initial}}$

$$m = \frac{w}{2}$$
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 $\delta_{\text{initial}}$
            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
        $\delta_{\text{new}}$ from the left. Determine whether $\delta_{\text{new}}$ is within the reduced
        matching tolerance, $m/2$. If so, consider the zero-crossing
        fragments matched with disparity $\delta_{\text{final}} = \delta_{\text{new}} + \delta_{\text{initial}}$

Coarse-scale zero-crossings:

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

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Ignore coarse-scale disparities:

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