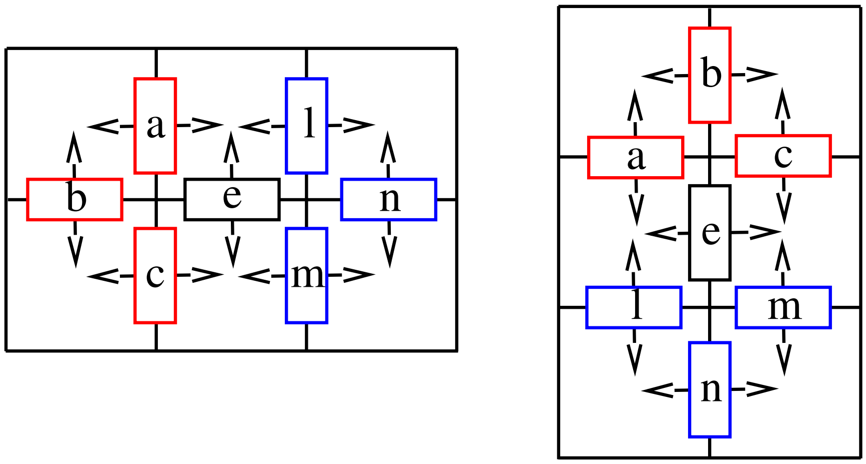
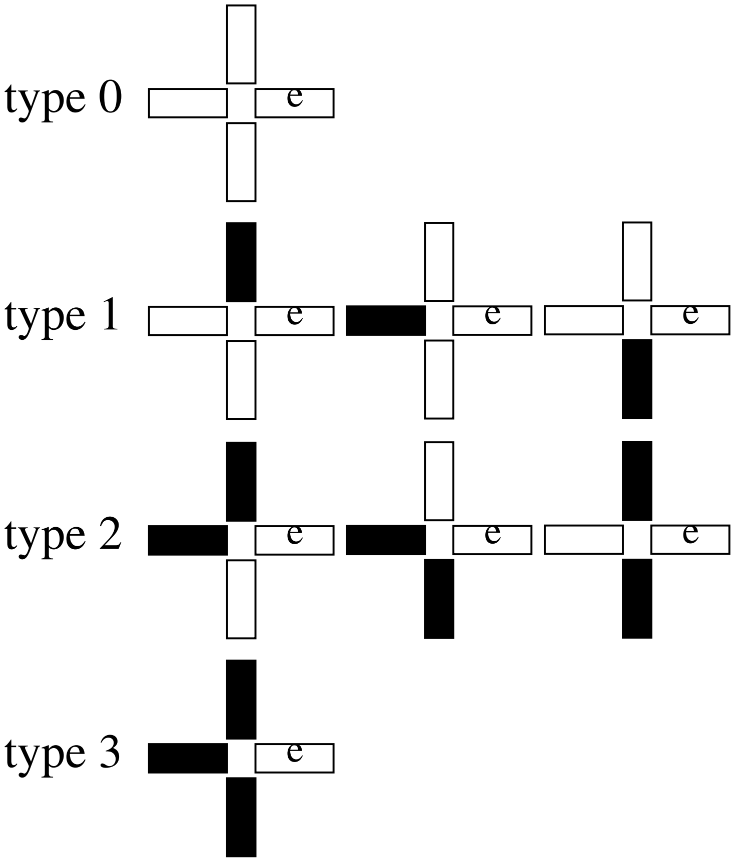
Edge Relaxation - Linking Contiguous Edges

Any edgelet that is truly part of a larger, continuous contour should have corroborating edgelets representing the continuation of the contour in its neighborhood.

Left-Right and Top-Bottom Neighborhoods



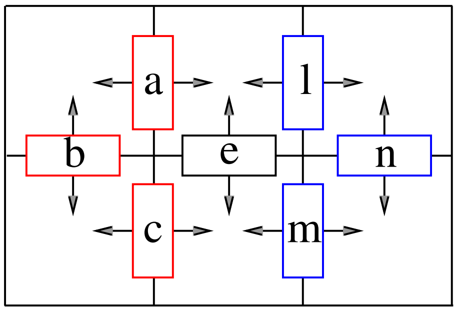
Edge Relaxation - Continuation Types



- q - gradient magnitude threshold
- $0 \leq (a, b, c) \leq 1$ - normalized gradient magnitudes, $a > b > c$,
- $m = max(a, b, c, q)$.

$$
\begin{array}{lr}
conf[0] = (m-a)(m-b)(m-c) & a, b, c < q \\
conf[1] = a(m-b)(m-c) & a > q; b, c < q \\
conf[2] = ab(m-c) & a, b > q; c < q \\
conf[3] = abc & a, b, c > q
\end{array}
$$

Edge Relaxation - Continuation Heuristics



$$\left.\begin{matrix}0-0\\0-2\\0-3\end{matrix}\right\}\text{NEGATIVE EVIDENCE} \Rightarrow C^{k+1}(e) = max(0, C^k(e) - \delta)$$

$$\left.\begin{matrix}1-1\\1-2\\1-3\end{matrix}\right\}\text{POSITIVE EVIDENCE} \Rightarrow C^{k+1}(e) = min(1, C^k(e) + \delta)$$

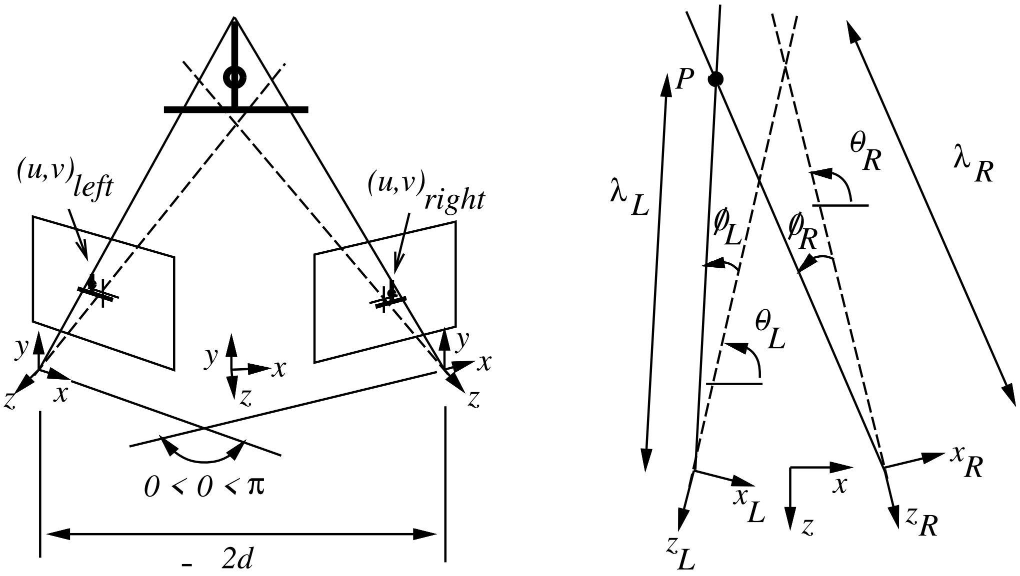
$$\left.\begin{matrix}0-1\\2-2\\2-3\\3-3\end{matrix}\right\}\text{NUETRAL EVIDENCE}$$

Hough Transform

with some knowledge about the shapes of an objects of interest, a so-called "voting" algorithm can be used to identify probable instances of the object

consider the family of lines described by the slope-intercept form

Recovering Space - Binocular Stereopsis

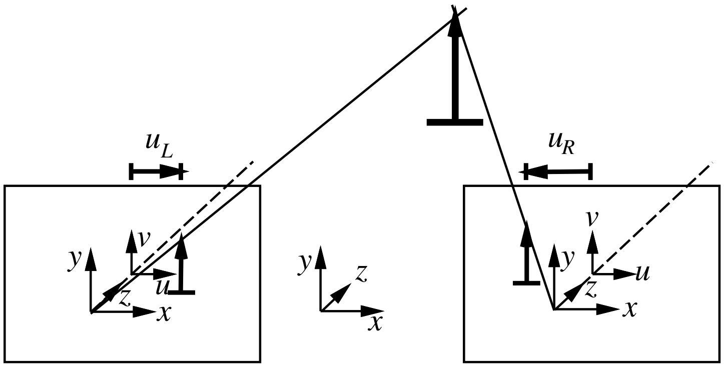


$$\lambda_L cos(\gamma_L) - d = \lambda_R cos(\gamma_R) + d$$
$$\lambda_L sin(\gamma_L) = \lambda_R sin(\gamma_R),$$

$$\lambda_L = \frac{2d sin(\gamma_R)}{sin(\gamma_R - \gamma_L)}$$
$$\lambda_R = \frac{2d sin(\gamma_L)}{sin(\gamma_R - \gamma_L)}$$

Depth by **vergence** and **disparity**.

Depth Encoded as Disparity



Consider this simple binocular configuration. In this geometry, the stereo system encodes depth entirely in terms of disparity. Under these conditions

$$u_L = \frac{f(x-d)}{z} \qquad u_R = \frac{f(x+d)}{z}$$

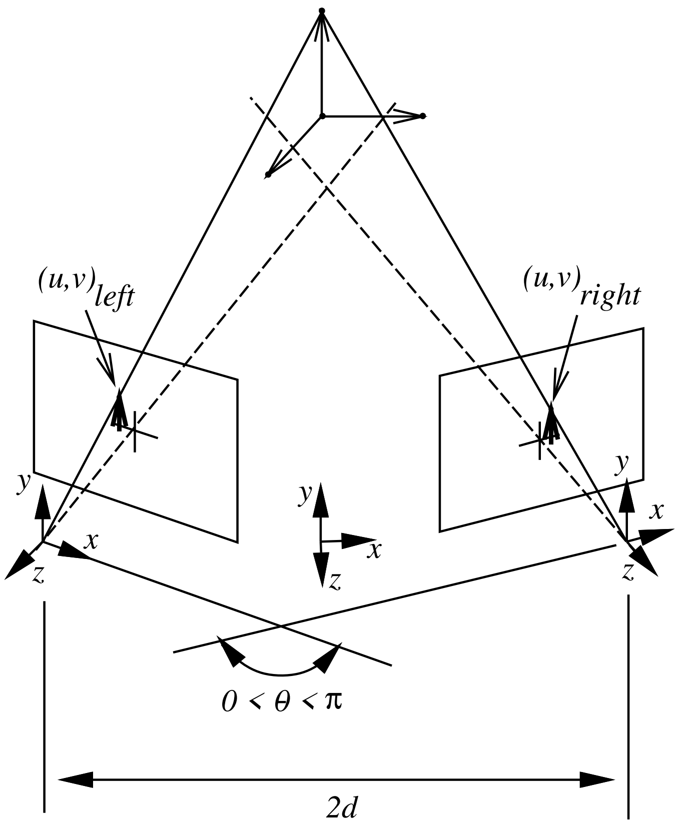
$$\begin{aligned} zu_R &= f(x+d) \\ zu_L &= f(x-d) \end{aligned}$$

$$z(u_R - u_L) = 2df$$

So by eliminating x , we may solve directly for z

$$z = \frac{2df}{(u_R - u_L)}$$

Weak Perspective Affine Transformations



$$\begin{bmatrix} u_L \\ v_L \\ u_R \\ v_R \end{bmatrix} = \begin{bmatrix} A_{00} & A_{01} & A_{02} & A_{03} \\ A_{10} & A_{11} & A_{12} & A_{13} \\ A_{20} & A_{21} & A_{22} & A_{23} \\ A_{30} & A_{31} & A_{32} & A_{33} \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

Weak Perspective - cont.

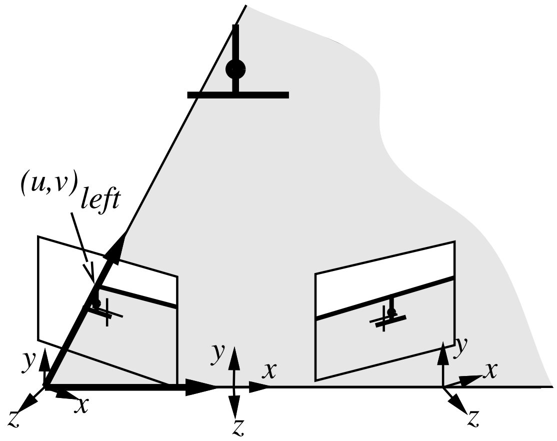
With 4 non-coplanar points, this leads to
16 equations in 16 unknowns

or since;

$$\begin{bmatrix} u_L^0 \\ u_L^1 \\ u_L^2 \\ u_L^3 \end{bmatrix} = \begin{bmatrix} A_{00}x^0 & A_{01}y^0 & A_{02}z^0 & A_{03} \\ A_{00}x^1 & A_{01}y^1 & A_{02}z^1 & A_{03} \\ A_{00}x^2 & A_{01}y^2 & A_{02}z^2 & A_{03} \\ A_{00}x^3 & A_{01}y^3 & A_{02}z^3 & A_{03} \end{bmatrix}$$

the solution can be obtained from $4 \times$ (4 *equations in* 4 *unknowns*)

The Epipolar Constraint



Epipolar plane: defined by the line joining the focal points of the stereo system and the ray from the left focal point to the image feature of interest.

Epipolar line: The intersection of the epipolar plane on the left and right image planes.

Alternatively, the inverse of the Amatrix:

$$\begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} A_{00}^{-1} & A_{01}^{-1} & A_{02}^{-1} & A_{03}^{-1} \\ A_{10}^{-1} & A_{11}^{-1} & A_{12}^{-1} & A_{13}^{-1} \\ A_{20}^{-1} & A_{21}^{-1} & A_{22}^{-1} & A_{23}^{-1} \\ A_{30}^{-1} & A_{31}^{-1} & A_{32}^{-1} & A_{33}^{-1} \end{bmatrix} \begin{bmatrix} u_L \\ v_L \\ u_R \\ v_R \end{bmatrix}$$

the forth column yields:

$$1 = A_{03}^{-1} u_L + A_{13}^{-1} v_L + A_{23}^{-1} u_R + A_{33}^{-1} v_R$$

Vision Programming Environment

IMAGE structure

```
typedef struct {
   int width, height, maxval;
   int *image;
} IMAGE;
```

read_image()

• reads *.pgm* format and converts it to an IMAGE data structure

remap()

• given IMAGE structure with associated *min* and *max*, remaps image onto 0-255 so that it may be written in *.pgm* format

write_image()

• writes IMAGE data structure out to disk in the *.pgm* format

Stereo Reconstruction Homework

Image Datasets

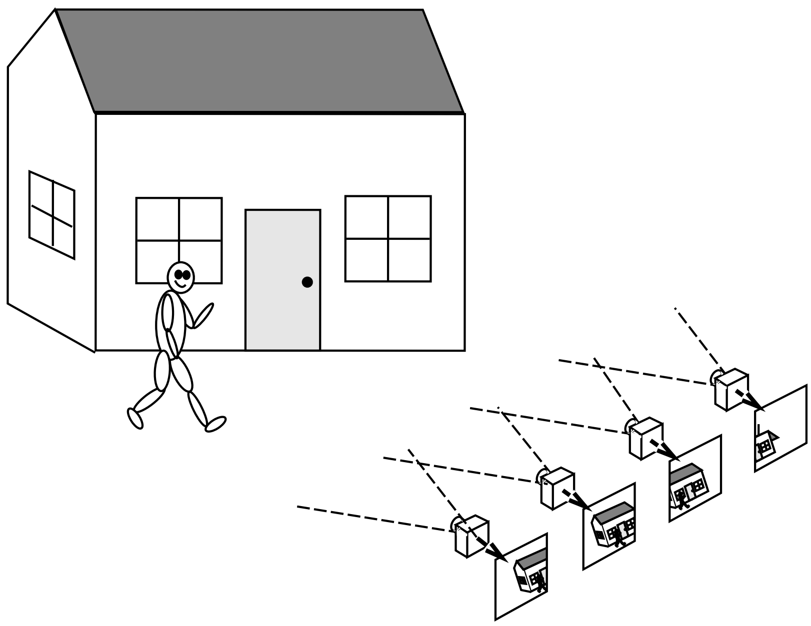
multiple images of static scenes from simple polyhedra to complex model train sets taken with a *scientific camera* at the Calibrated Imaging Laboratory at CMU.

```
ftp ftp.cs.cmu.edu
login: anonymous
passwd: [your email]
cd /usr0/anon/project/cil
binary
dir
get cil-0001.tar
etc.
```

or

http://www.cs.cmu.edu:8001/usr0/anon/project/cil/html/cil-ster.html

Stereo Reconstruction Homework



Left Image
c-000101.pgm
c-000101.par

Right Image
c-000103.pgm
c-000103.par

Parameter Files:

- dimension of a pixel
- pinhole camera effective focal length
- world-camera translation
- world-camera rotation