Depth and Shape Inference (II)

Introduction to Computational and Biological Vision

CS 202-1-5261

Computer Science Department, BGU

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Edge and boundary Interpretation

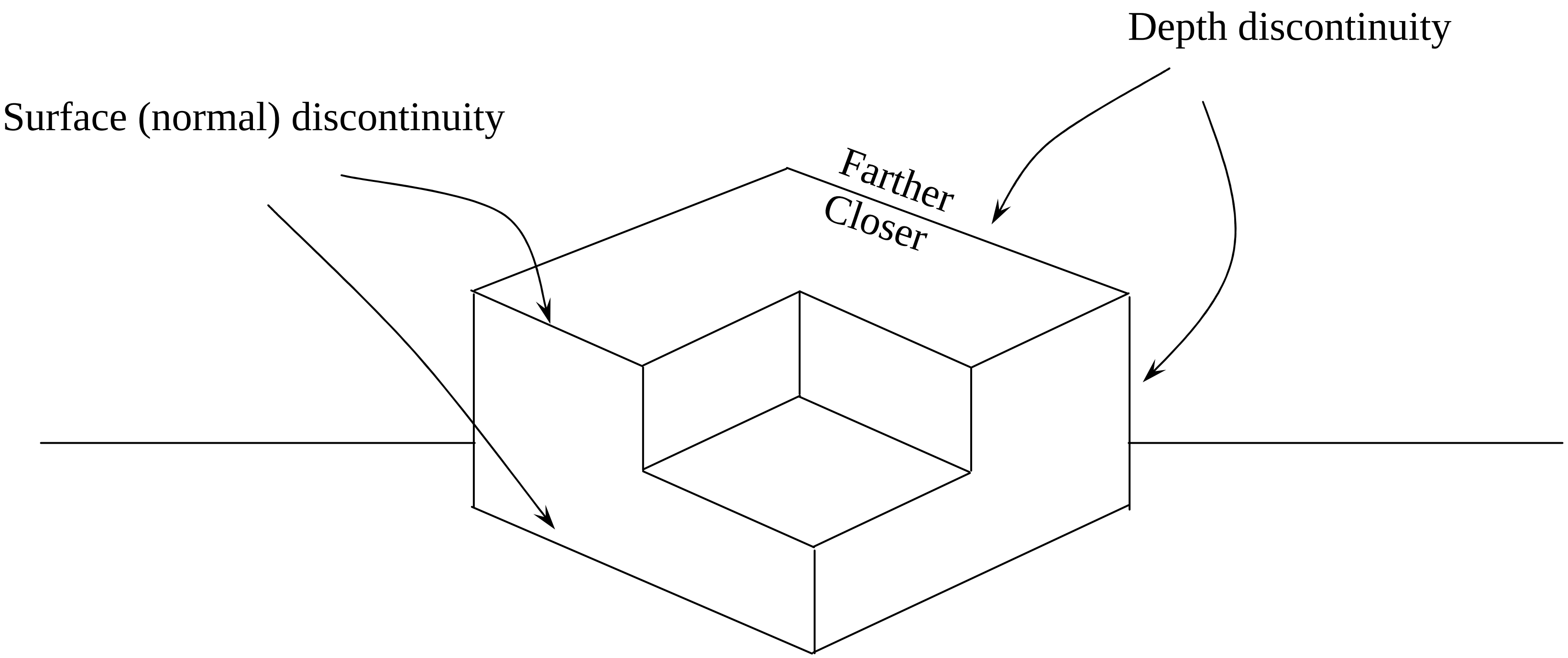
A (desired) edge detection mapping (labeling)

$$E[I(x,y)]: R^2 \rightarrow \Lambda = \{0,1,2,3,4,5,\ldots\}$$

$$E[I(x,y)] = \begin{cases} 1 & \textbf{(x,y) is a boundary point} \\ 2 & \textbf{(x,y) is a surface discontinuity point} \\ 3 & \textbf{(x,y) is an illumination discontinuity point} \\ 4 & \textbf{(x,y) is a reflectance discontinuity point} \\ \vdots & \\ 0 & \textbf{Otherwise (non edge point)} \end{cases}$$

Edge and boundary Interpretation

Edge/Contour interpretation = Determination of physical cause

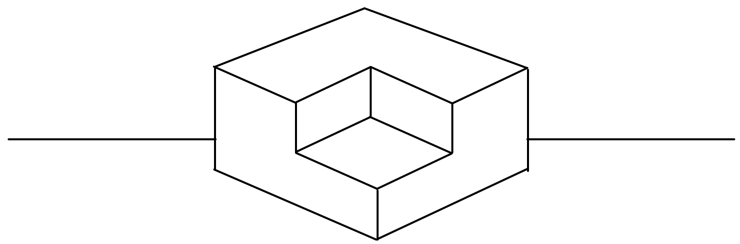


Edge and boundary Interpretation

1968	**Guzman**	•The SEE program
1971	**Huffman / Clowes**	•Formal analysis of block world •polygonal planar surfaces •Depth and surface discontinuities only •trihedral vertices
1972	**Waltz**	•Shadow boundaries •Cracks
1974	**Turner**	•Opaque solids with limited class of smooth surfaces
1987	**Malik**	•Curved objects with C^3 faces
⋮	⋮	⋮

Edge and boundary Interpretation

Block worlds

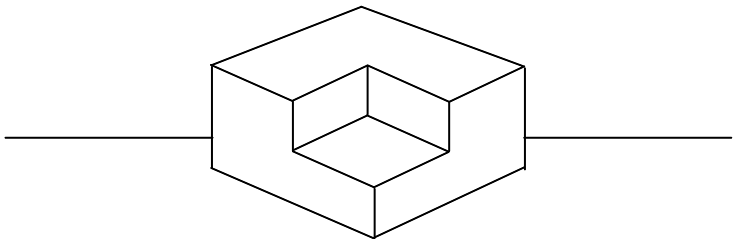


- **polygonal objects**
  - Planar faces
  - trihedral vertices
- **Allowed discontinuities**
  - Depth discontinuities
  - Surface normal discontinuities
- **Ignored discontinuities**
  - Illumination discontinuities (shadows)
  - Reflectance (pigmentation/color) discontinuities
- **General viewpoint assumption:**

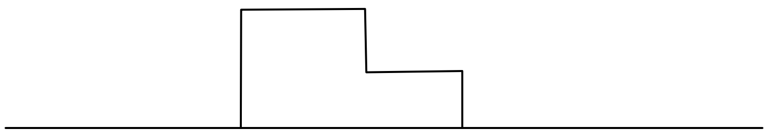
Edge and boundary Interpretation

General viewpoint assumption

A viewpoint is general (as opposed to accidental) if a small perturbation of it would not affect the configuration of the line drawing (no qualitative change).



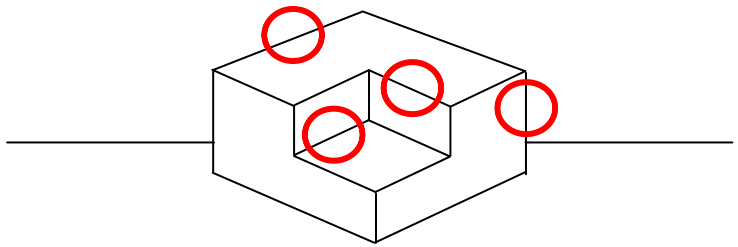
General

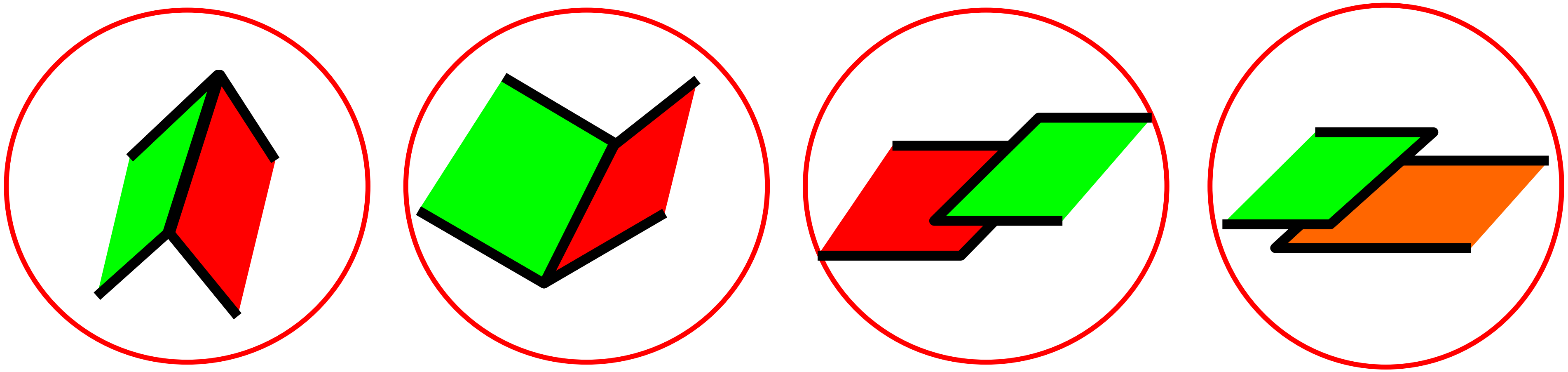


Accidental

Edge and boundary Interpretation

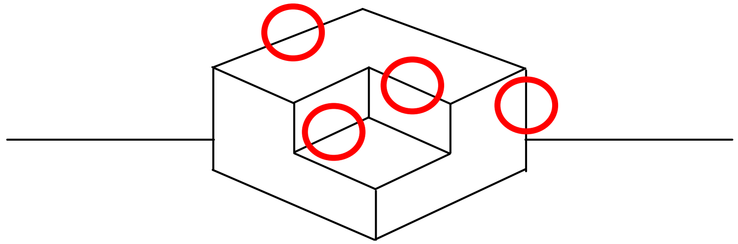
Edge types

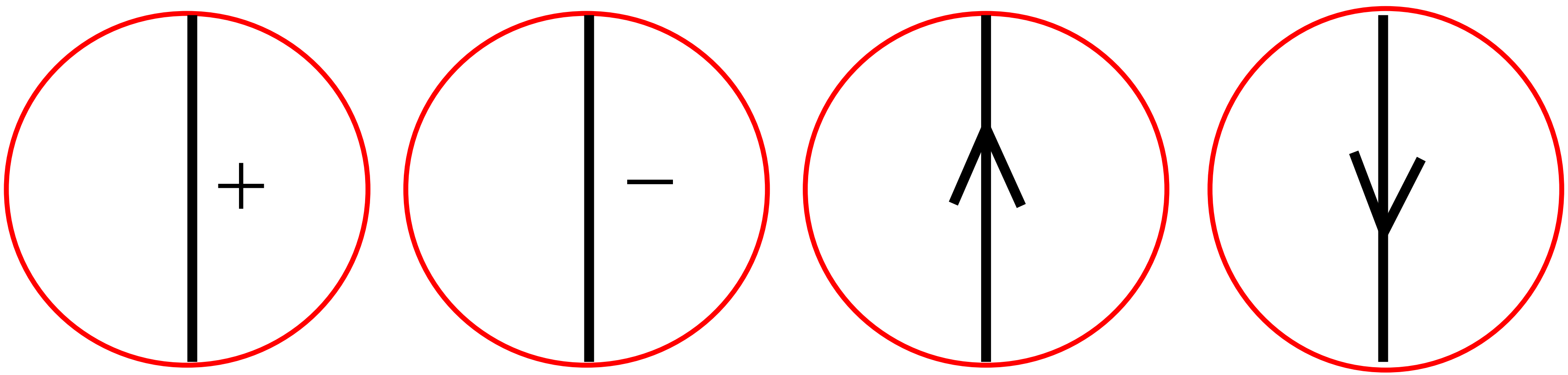




Edge and boundary Interpretation

Edge types





Convex
orientation edge

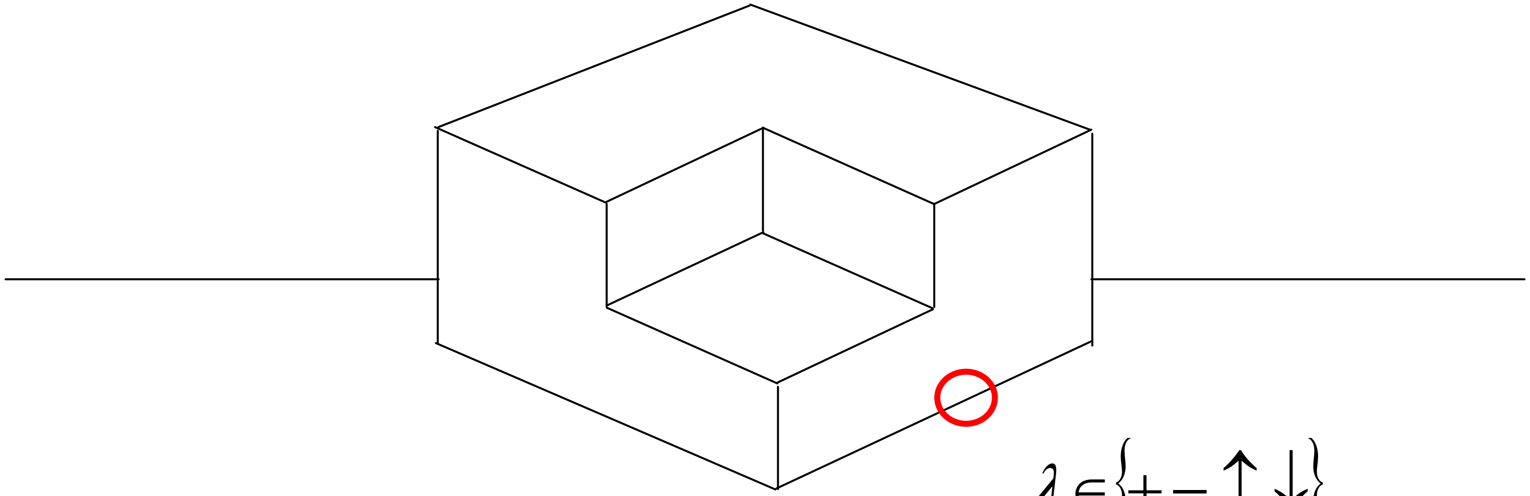
Concave
orientation edge

Depth edge

Depth edge

Edge and boundary Interpretation

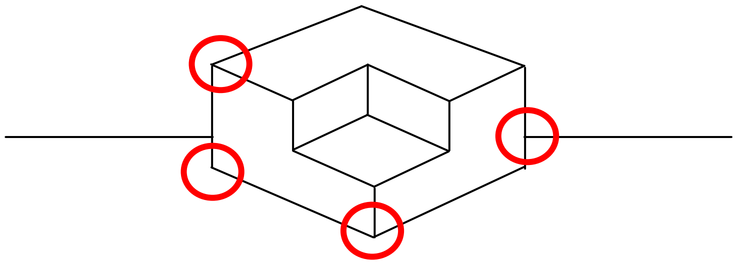
Edge interpretation = Edge labeling

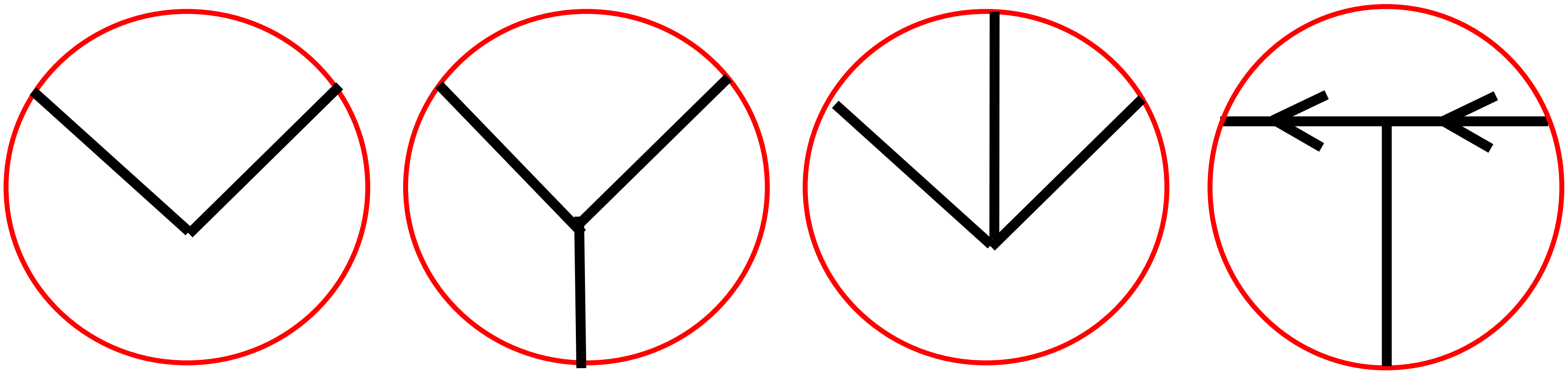


$$\lambda \in \{+, -, \uparrow, \downarrow\}$$

Edge and boundary Interpretation

Edge intersections (vertices)





V-junction
(L-junction)

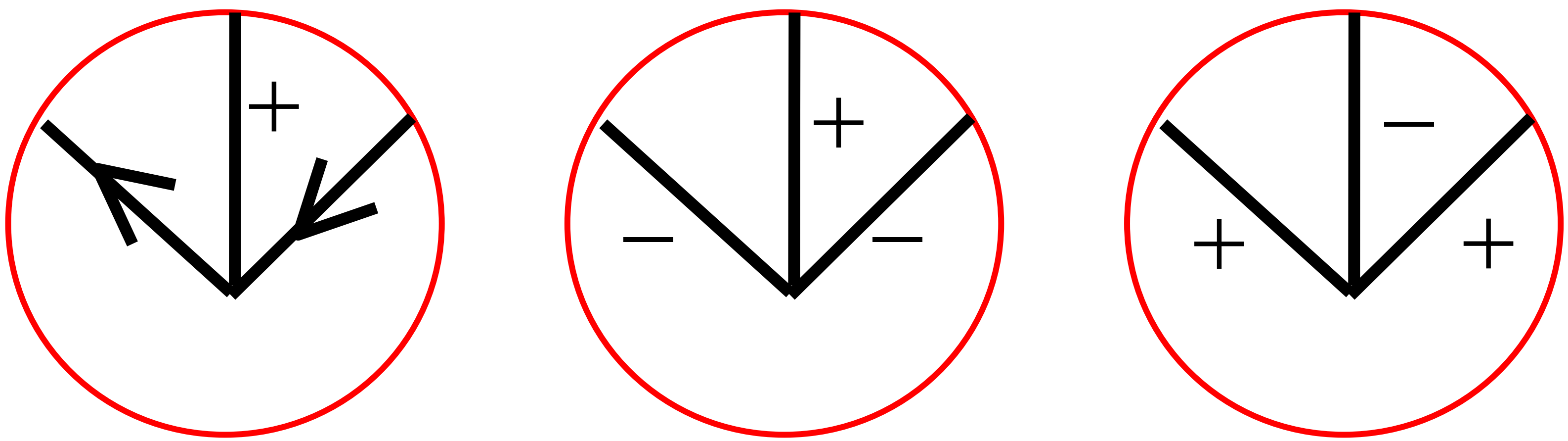
Y-junction

W-junction
(arrows)

T-junction

Edge and boundary Interpretation

Physical constraints on labeling of edge intersections

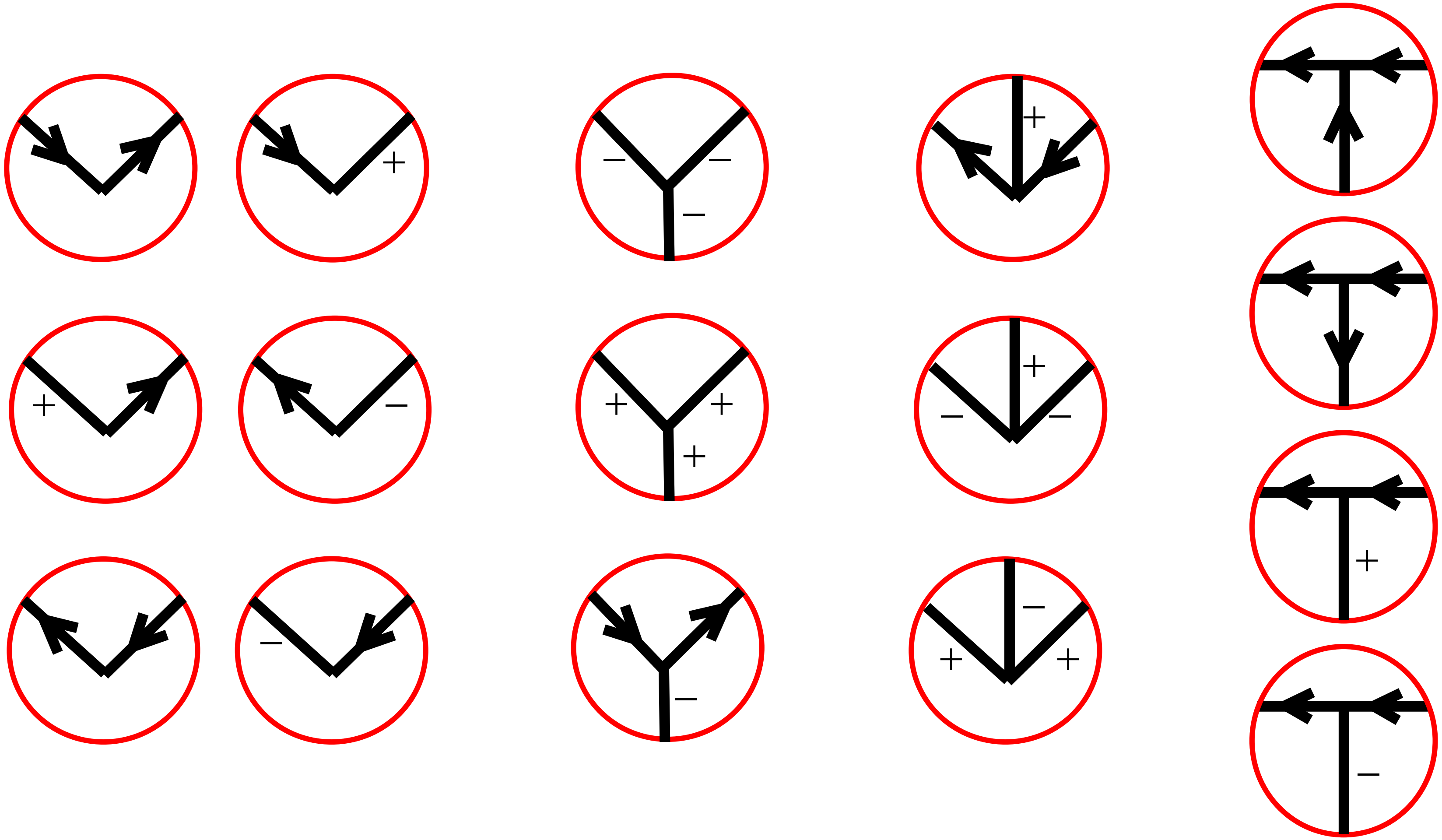


Physical constraints on arrow junctions

[Huffman 1971, Clowes 1971]

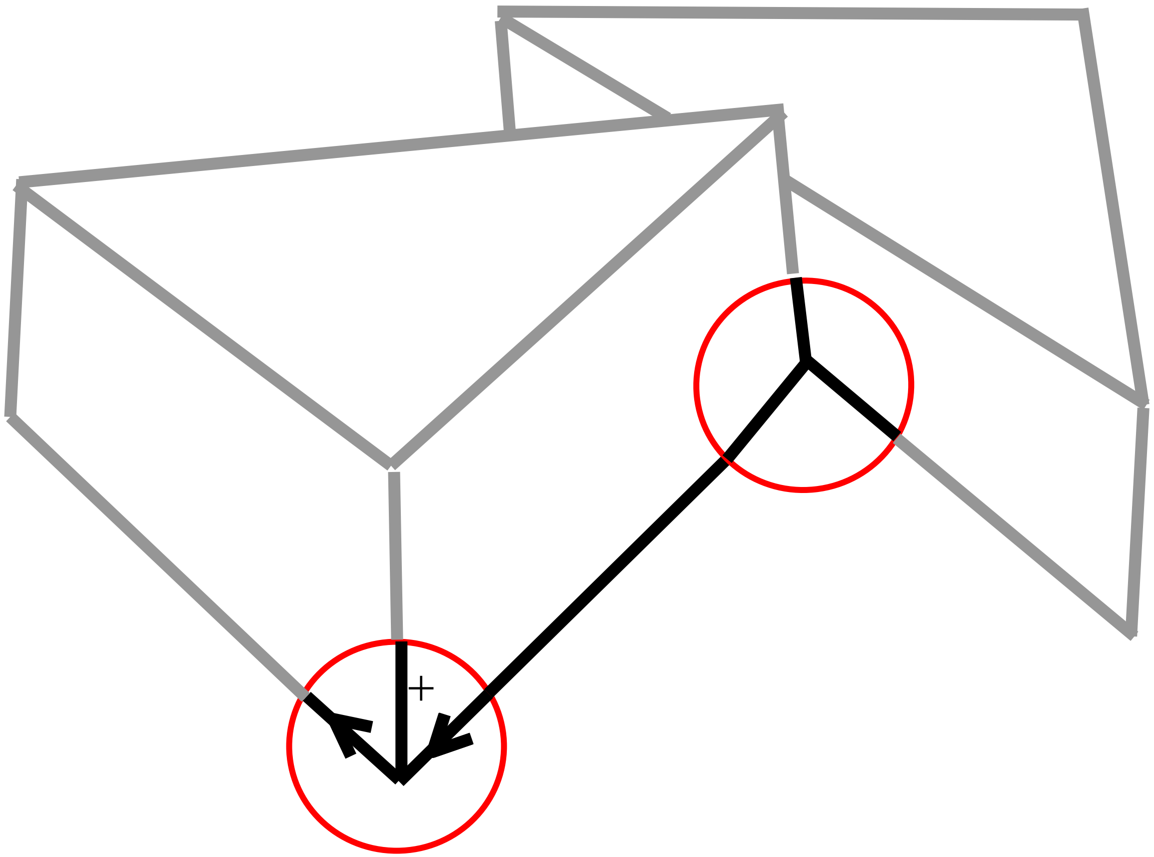
Edge and boundary Interpretation

Huffman and Clowes complete catalog (1971)



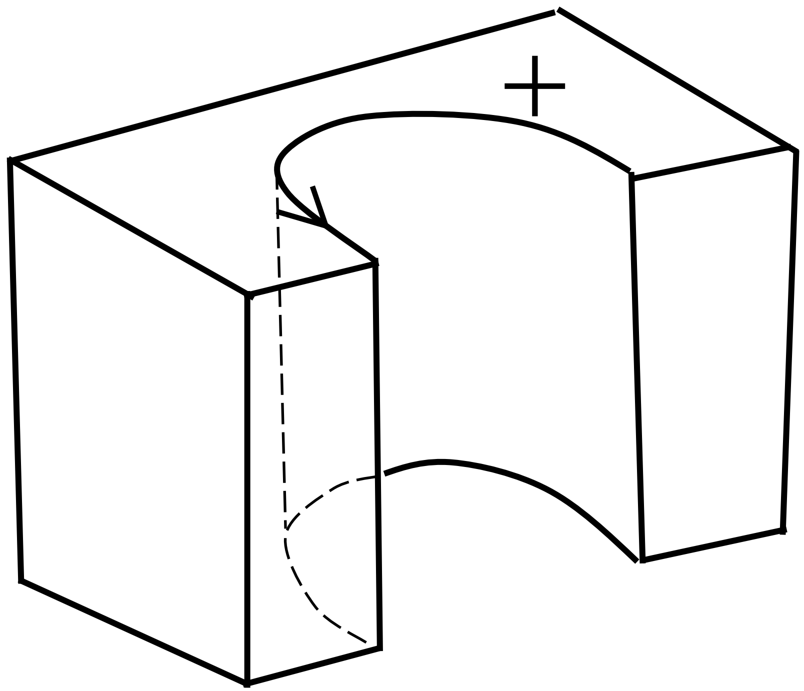
Edge and boundary Interpretation

Constancy of interpretation along edges



Edge and boundary Interpretation

Constancy of interpretation along edges

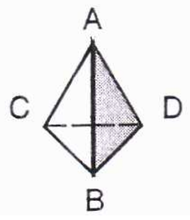


Not valid for curved objects

Edge and boundary Interpretation

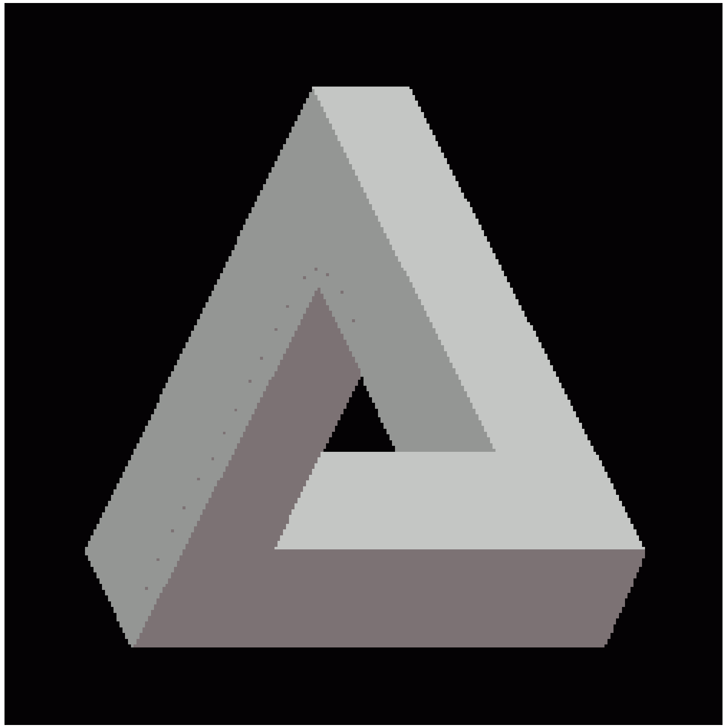
Using constraints to label line drawings

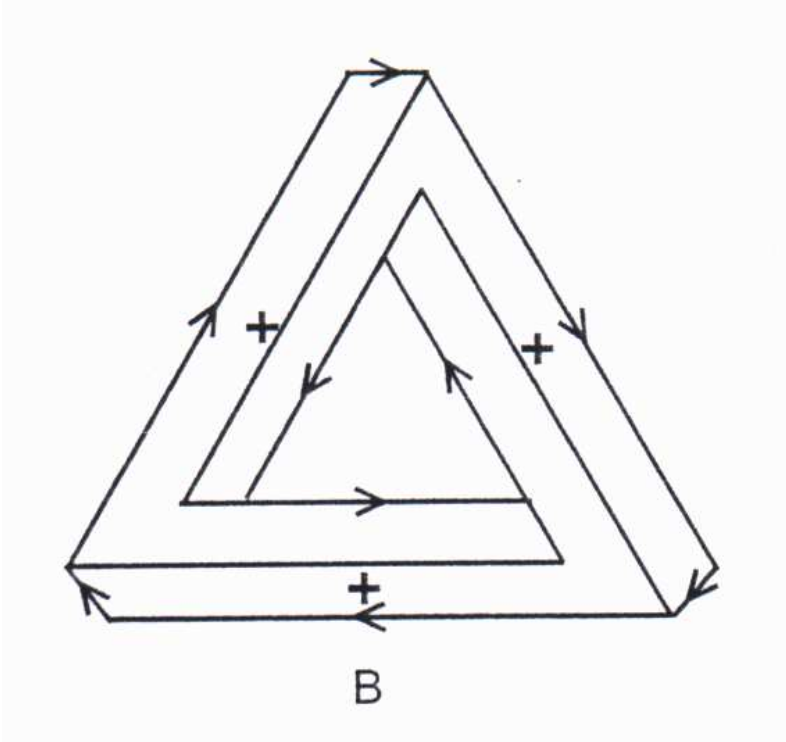
Unlabeled drawing



Edge and boundary Interpretation

Consistent labeling is a necessary condition





…but not a sufficient one

Edge and boundary Interpretation

Consistent line drawing labeling via sequential search and backtracking

1. Form a graph representation $G=(V,E)$ of the line drawing with vertices as nodes line drawing edges as graph edges
2. Assume some (arbitrary) ordering between edges $E=\{e_1,e_2,\ldots e_n\}$
3. Set $i=1$
4. Label e_i with the next untried label from {+,-,<,>}
5. Using the catalog, check consistency of the new label with all adjacent labeled edges.
6. If consistent then increase i and go to step 4

   else backtrack

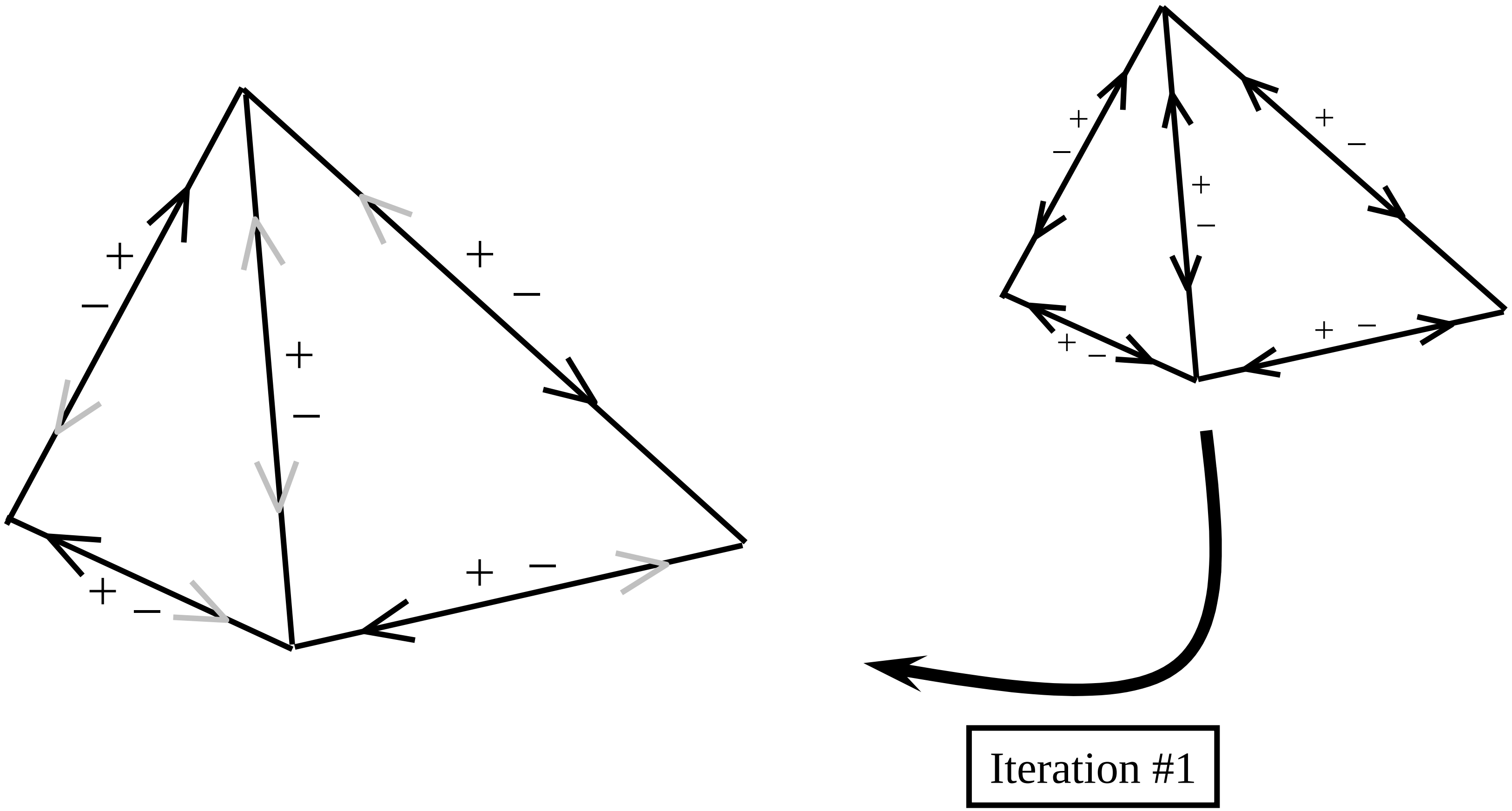
Edge and boundary Interpretation

Consistent line drawing labeling via relaxation labeling

1. Initial the label set for each line drawing label to {+,-,<,>}
2. Repeat at all edges concurrently until no label set decreases in size
   - If label *L* at edge *e* cannot form a consistent junction using available labels at edges intersecting *e* in a common vertex, filter *L* from *e*'s label set

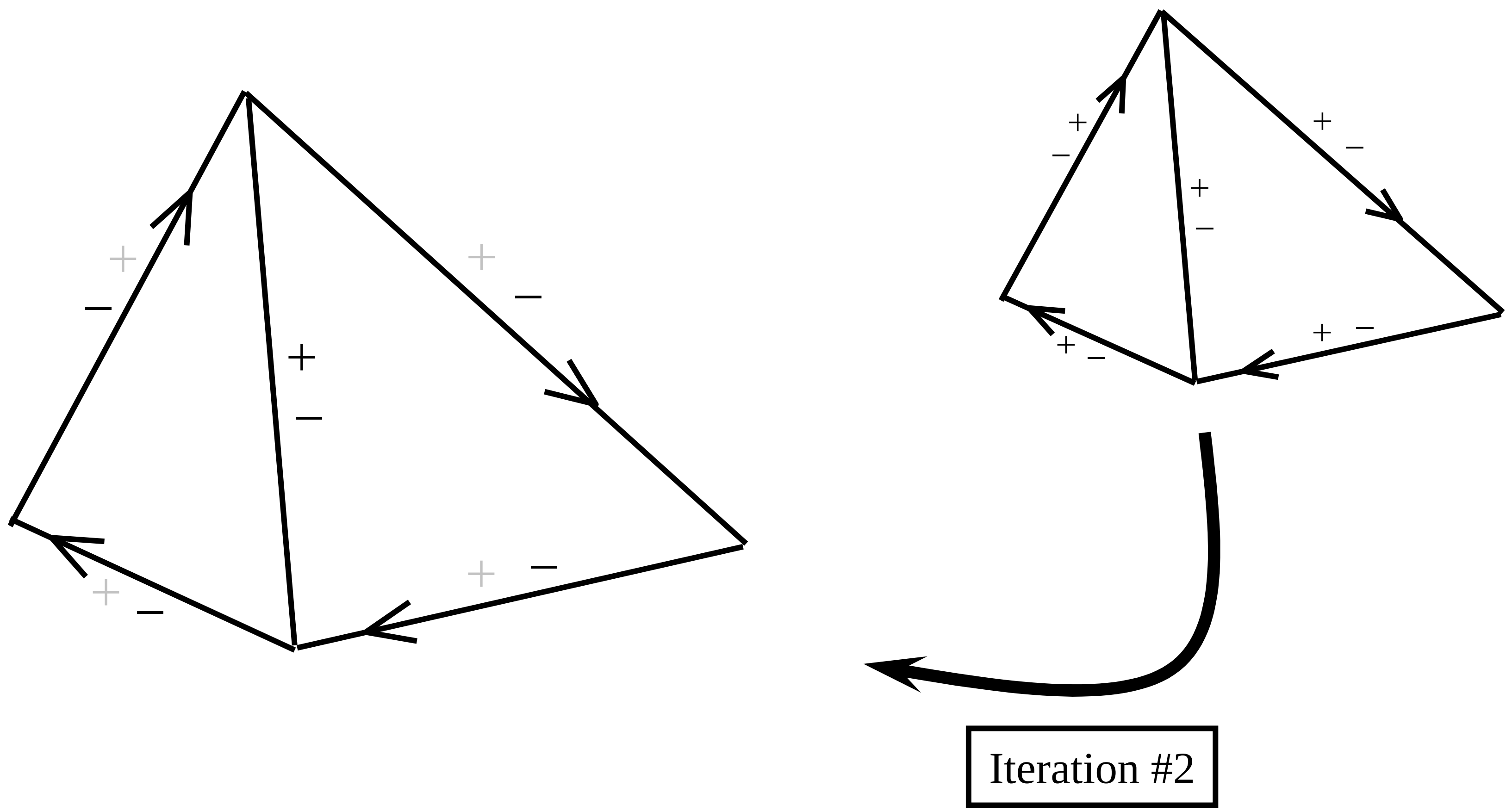
Edge and boundary Interpretation

Consistent line drawing labeling via relaxation labeling



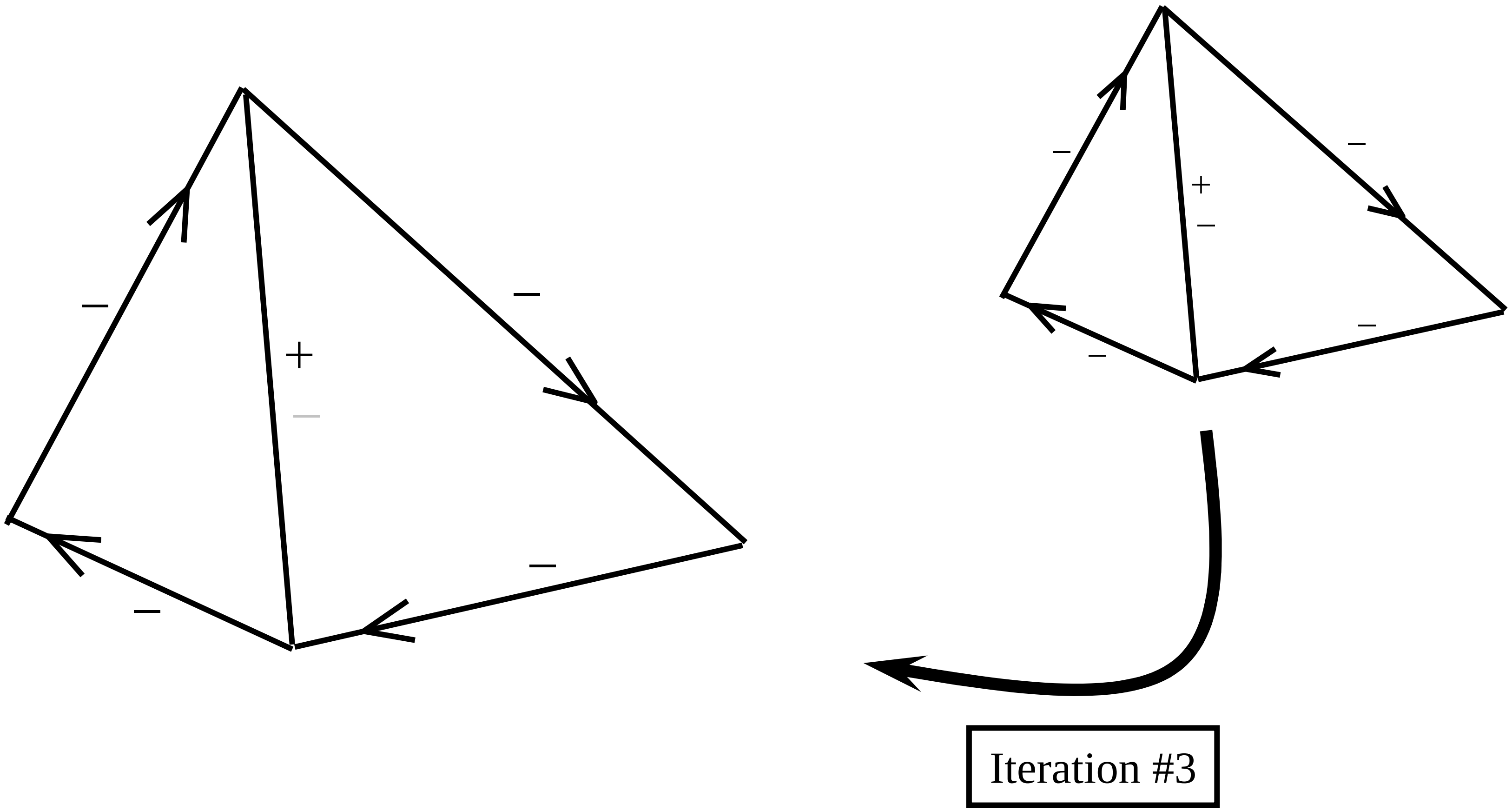
Edge and boundary Interpretation

Consistent line drawing labeling via relaxation labeling



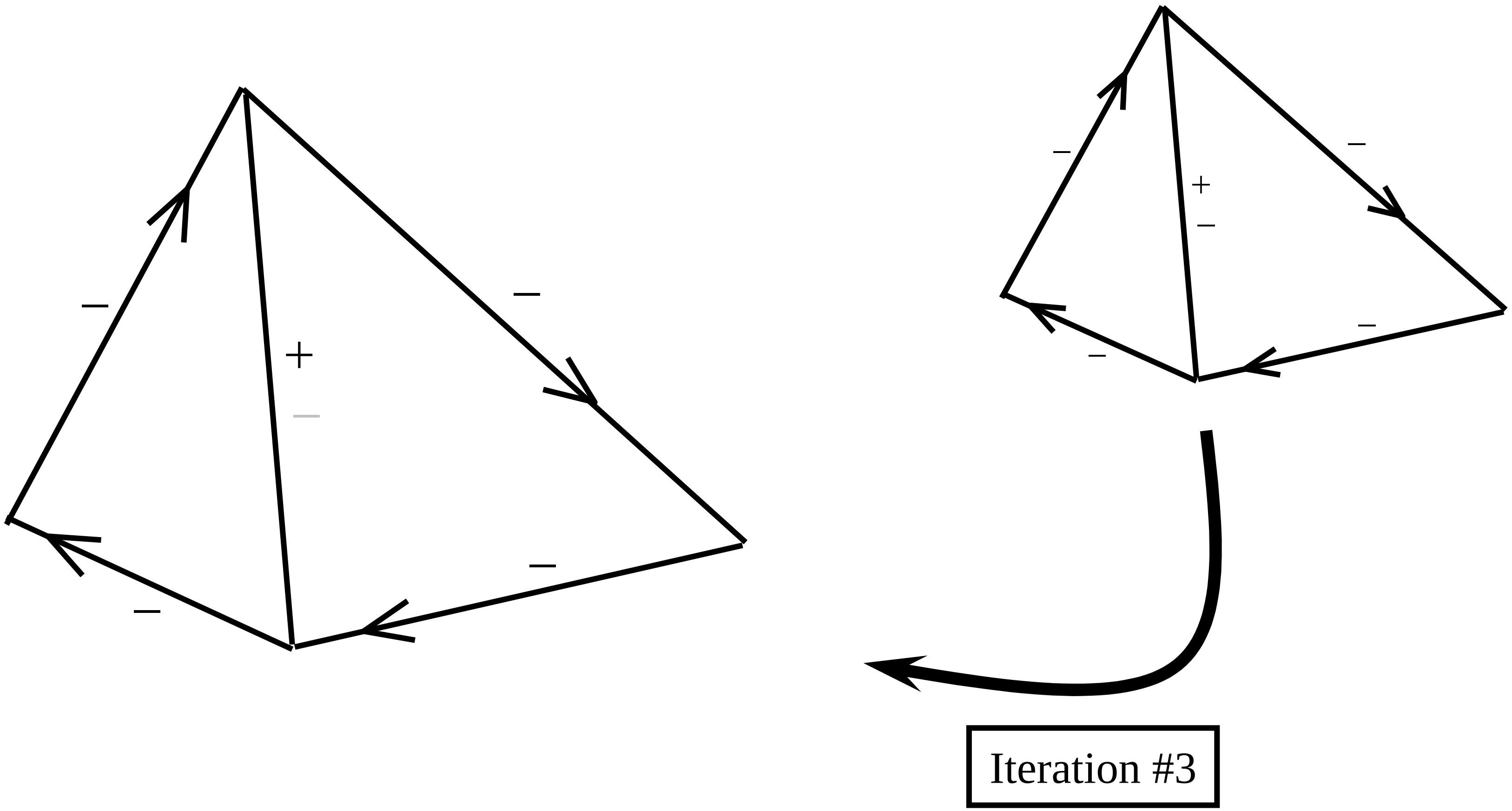
Edge and boundary Interpretation

Consistent line drawing labeling via relaxation labeling



Edge and boundary Interpretation

Consistent line drawing labeling via relaxation labeling



Edge and boundary Interpretation

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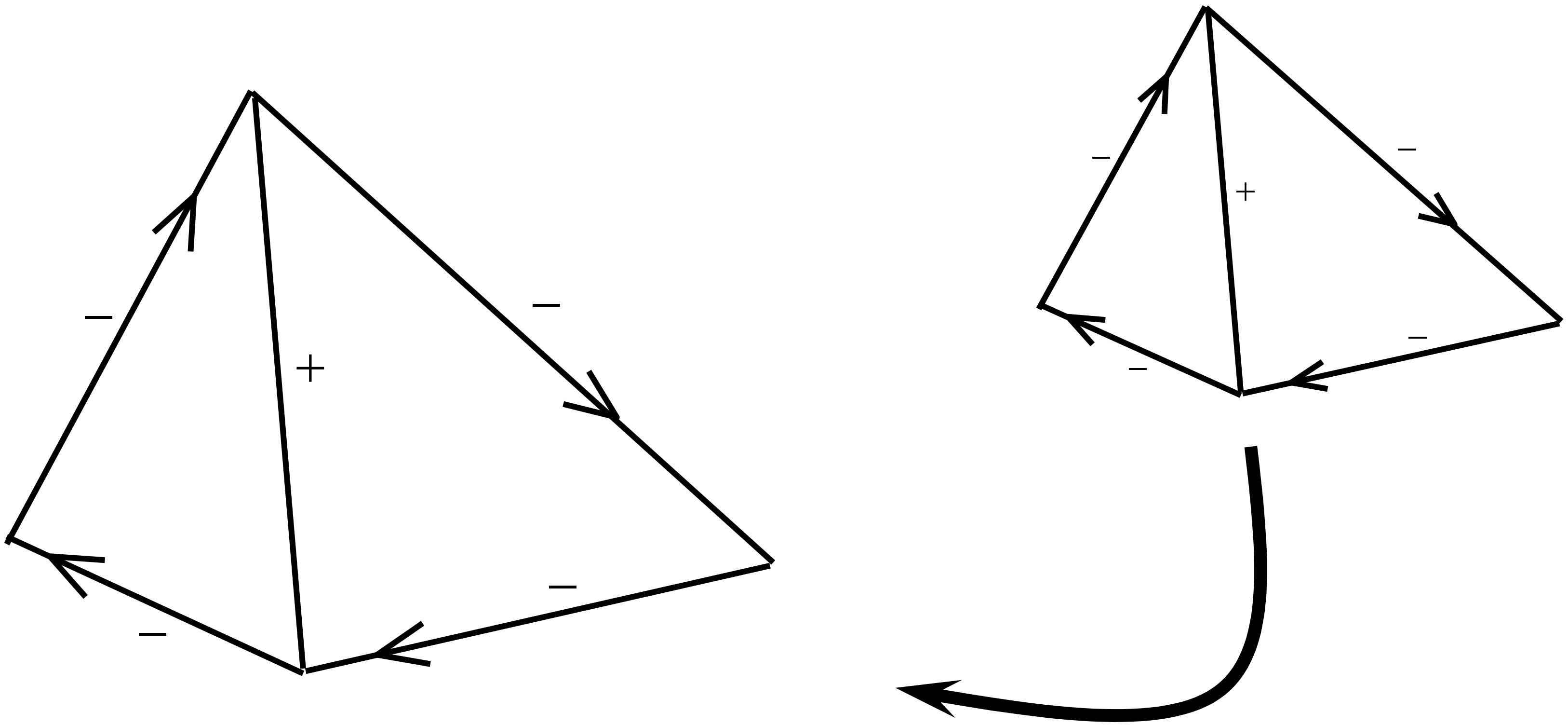
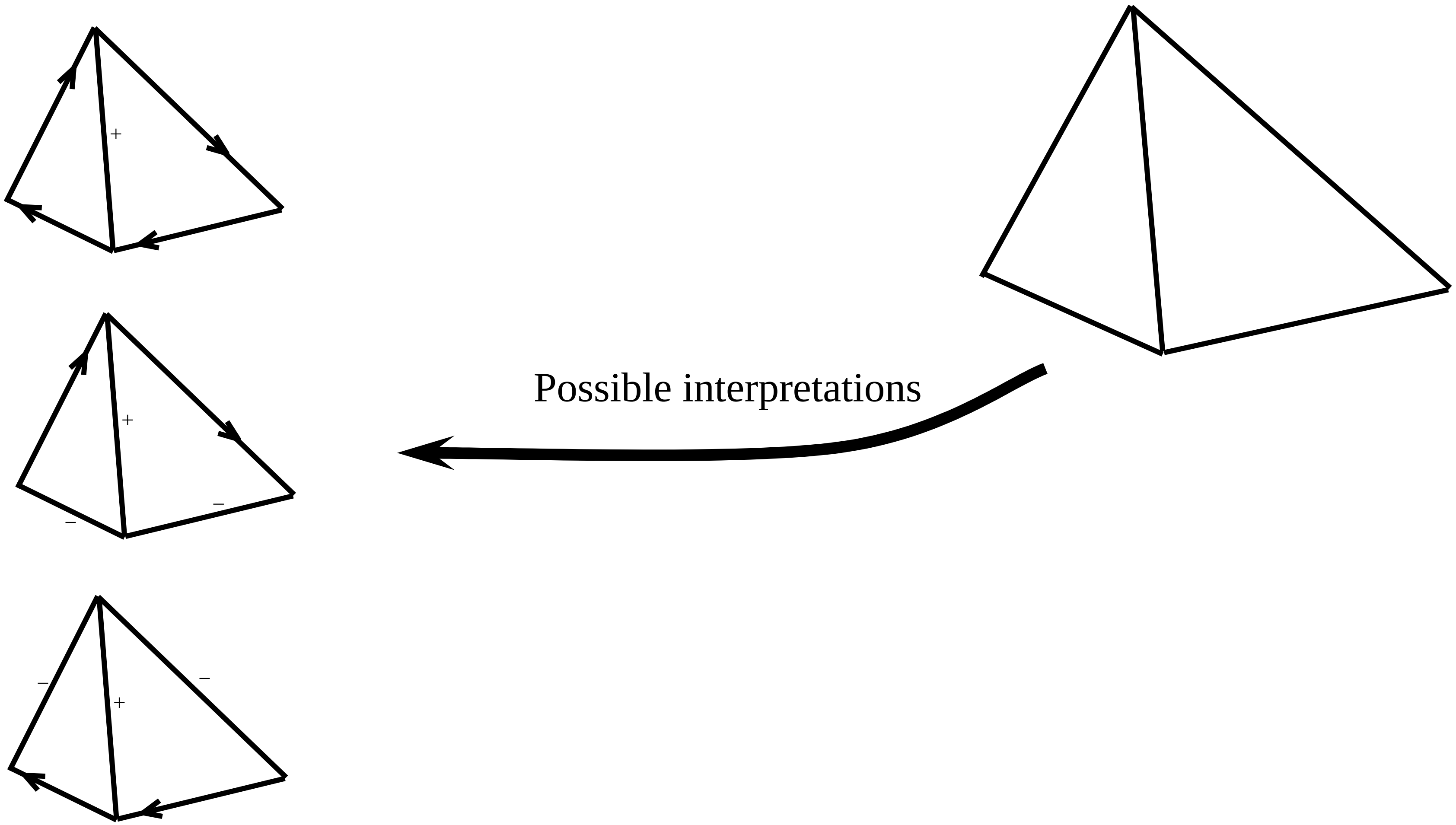


Iteration #4

Convergence state!!

Edge and boundary Interpretation

Consistent line drawing labeling via relaxation labeling



Edge and boundary Interpretation

Consistent line drawing labeling via relaxation labeling

$B = \{b_1, \ldots, b_n\}$ set of **objects** to be labeled

$\Lambda = \{1, 2, \ldots, m\}$ set of possible **labels**

$p_i^0(\lambda)$ the measured **confidence** that b_i should be labeled λ.
$p_i^0(\lambda) \geq 0$
$\sum_{\lambda=1}^{m} p_i^0(\lambda) = 1 \quad \forall i$

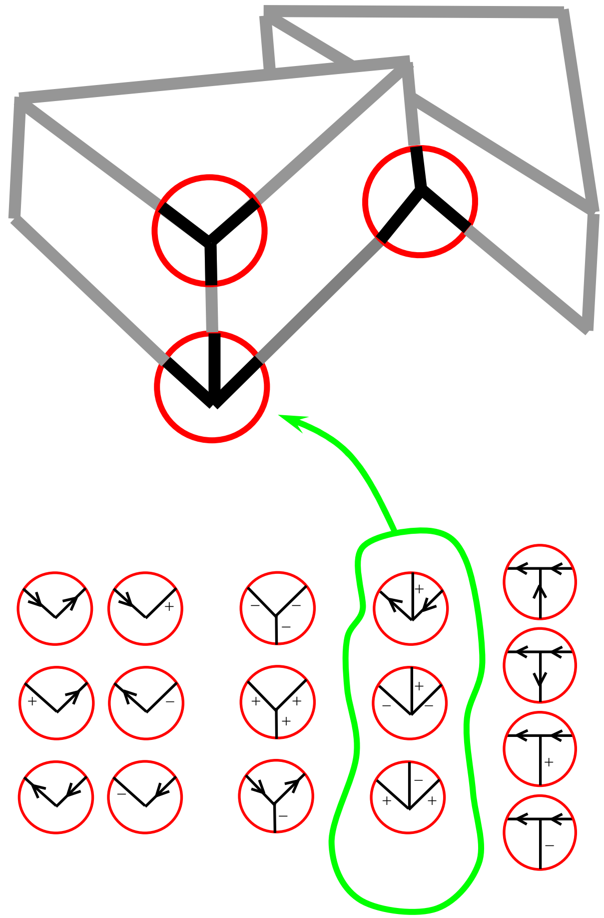
$r_{ij}(\lambda, \mu)$ $\Leftrightarrow$ the strength of **compatibility** between the hypotheses "b_i has label λ" and "b_j has label μ"

Edge and boundary Interpretation

Consistent line drawing labeling via relaxation labeling

Nodes = line drawing intersections

Labels = Vertex catalog



Edge and boundary Interpretation

Consistent line drawing labeling via relaxation labeling