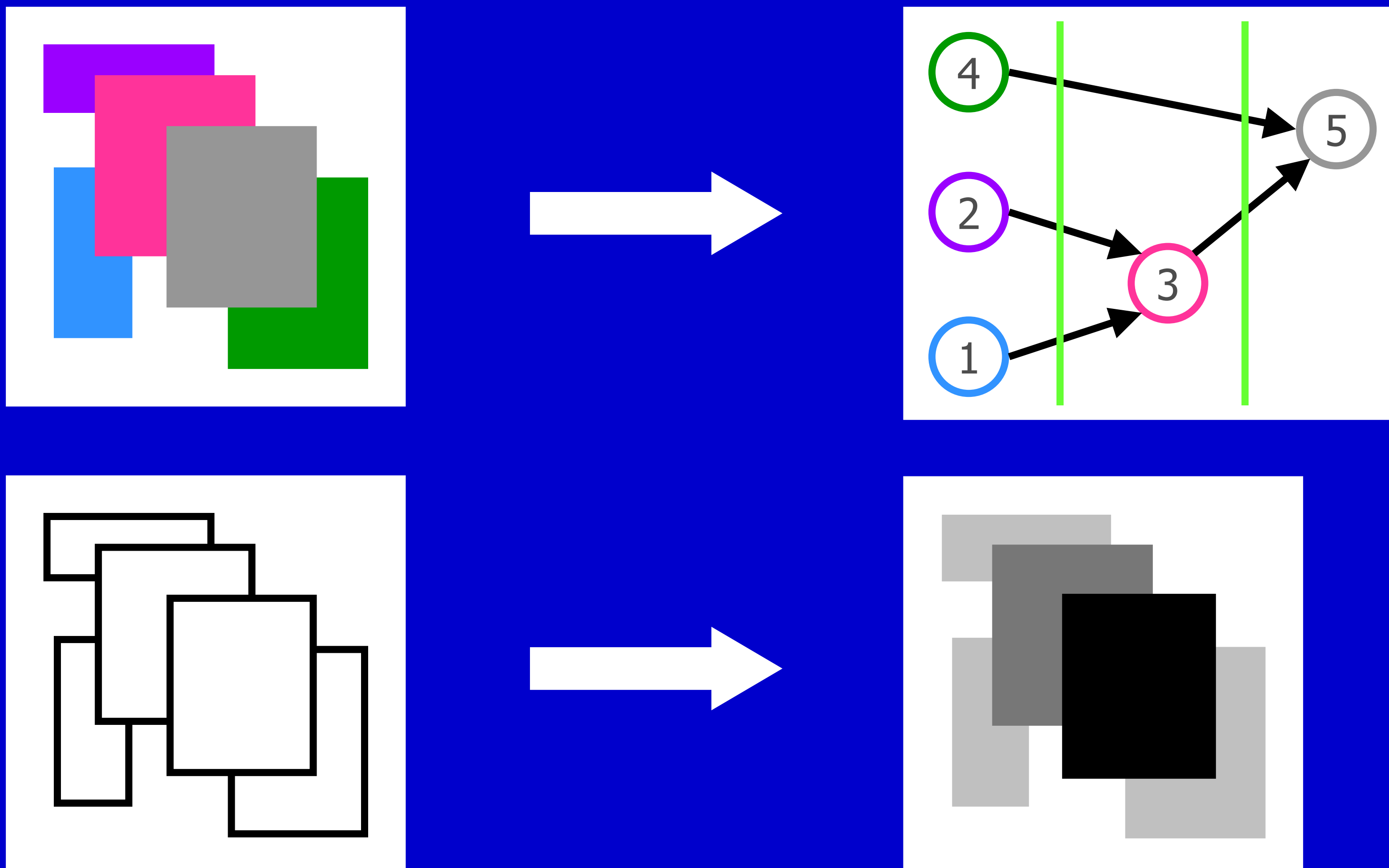
A Hierarchical Markov Random Field Model for Figure-ground Segregation

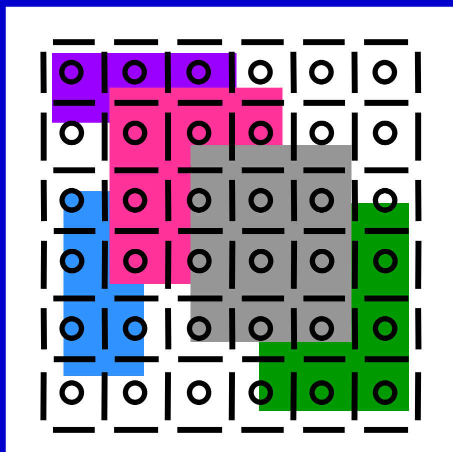
Stella X. Yu[1,3] *Tai Sing Lee*[2,3] *Takeo Kanade*[1,2]

Robotics Institute[1]
Department of Computer Science[2]
Carnegie Mellon University
Center for the Neural Basis of Cognition[3]

Goal: depth segregation given contours

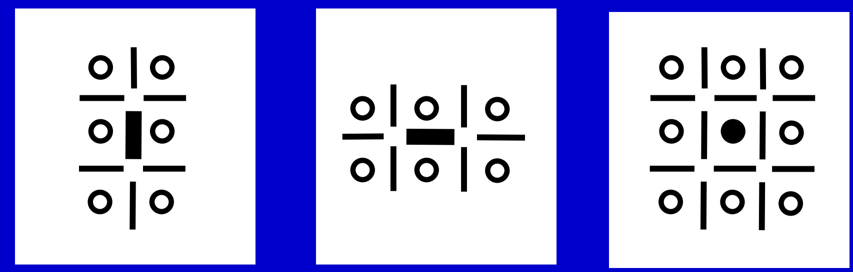


Markov Random Fields



Pixel and line sites

Neighbourhood systems:



Probability of a configuration:

$$P(\omega) = \frac{e^{-U(\omega)}}{Z}$$

$$U(\omega) = \sum_{c \in C} V_c(\omega)$$

$$Z = \sum_{\omega \in \Omega} e^{-U(\omega)}$$

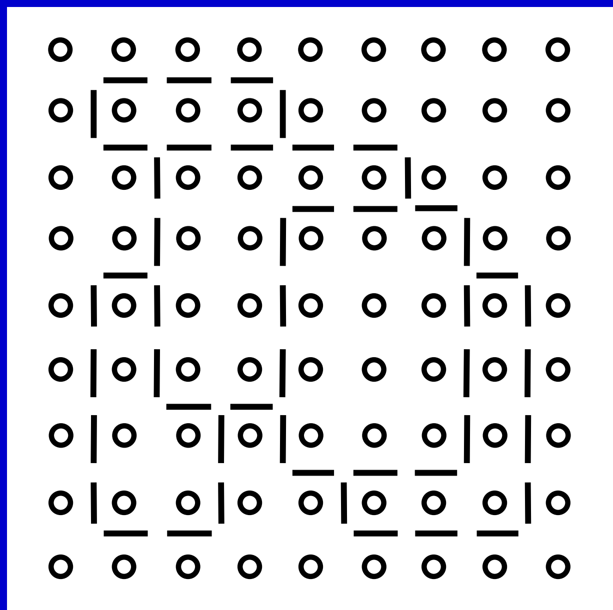
Encoding local decision rules

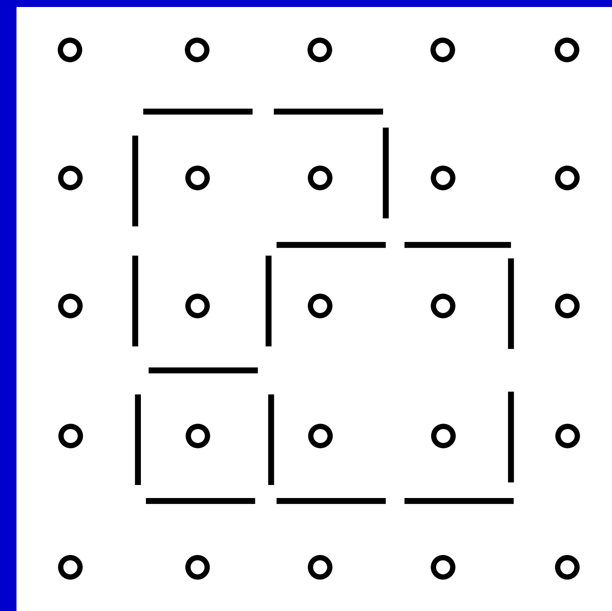
$$V_c(\omega) = \sum_t \beta_t \cdot \gamma(\text{depth map pattern}) \cdot \chi(\text{edge map pattern})$$

$$U_k(\omega) = x(\omega, k) \cdot \beta$$

- ✓ Depth continuity within surfaces and discontinuity across edges
- ✓ Depth continuity along contours
- ✓ Depth discontinuity at T-junctions
- ✓ Depth interaction between surface and contours: border ownerships

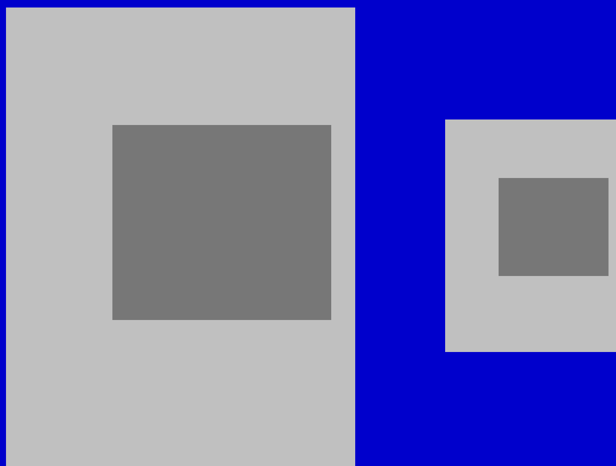
Multi-scale Hierarchy





Configurations at a higher level depend on
both the edge map and depth instantiation at a lower level.

Topology depends on depth polarity



Preservation of topology for overlapping shapes.

Reduction of topology for abutting shapes.

Parameter estimation by LP

$$\ln \frac{P(\omega_k = i \mid \omega_{\eta_k})}{P(\omega_k = j \mid \omega_{\eta_k})} = U_k(\omega') - U_k(\omega) = [x(\omega', k) - x(\omega, k)] \cdot \beta$$

$$[x(\omega', k) - x(\omega, k)] \cdot \beta < 0, \quad P(\omega_k = i \mid \omega_{\eta_k}) > P(\omega_k = j \mid \omega_{\eta_k})$$

$$\text{LP}: \quad \beta = \arg\min \ 1^{\mathrm{T}} \delta$$
$$\text{subject to}: A \cdot \beta - \delta < 0, \quad \delta \geq 0, \quad \beta \geq 1$$

Learning by rehearsals

- Step 1: Collect constraints by choosing intermediate configurations
- Step 2: Find beta by solving the LP
- Step 3: Examine the goodness of chosen configurations by the margin of the constraints
- Step 4: If the margins are acceptable, stop; otherwise, change the choice of intermediate configurations
- Step 5: Go to Step 1

Results with β from 2-object training sets