Connected Components Labeling (CCL)

- Find all connected, foreground pixel regions within a binary image
- Each pixel region, or connected component, receives a unique label
- Fundamental for image segmentation and object recognition
- CCL should be as fast as possible

### Heuristics – Concept

- **Shannon Entropy** (information theory)
  - Given a set of events $E$, with $P_i$ being the probability of an event $i \in E$, the entropy $H_E$ is:
    \[
    H_E = \sum_{i} -P_i \log P_i
    \]
  - Entropy describes the uncertainty of outcomes
- **Decision Tree Learning**
  - Recursively partition the dataset through entropy calculation
    1. Try splitting on every attribute
    2. Calculate Information Gain (IG) on subsets (IG measures average entropy reduction)
    3. Apply split with highest information gain
- **Entropy Partitioning Decision Tree (EPDT)** for the Rosenfeld mask is near-optimal

### History of CCL Research

- Rosenfeld and Pfaltz invented two scans algorithms
- Wu et al. proposed Optimal Decision Trees (ODTs)
- Grana et al. proposed block-based mask
- **What about 3D CCL?**
  - Multiple possible block-based masks: 2x1x1, 2x2x1 and 2x2x2
  - Explosion in complexity makes the ODT generation infeasible
  - Existing 3D CCL algorithms do not employ block-based masks
  - Goal: generate a near-optimal tree with a heuristic strategy

### Applying Decision Tree Learning to 3D CCL

- New 3D EPDT CCL algorithms
  - Varying block size and number of pixels
  - **EPDT_19c**
    - Block size 2x1x1
    - Smallest 3D block-based mask
  - **EPDT_22c**
    - Block size 2x1x1
    - Add borders pixels, for more efficient actions
  - **EPDT_26c**
    - Block size 2x2x1
    - Largest tree that compilers can handle

### Experimental Results

- EPDT algorithms improve the performance of the first scan by saving many memory accesses
- EPDT_26c has a very large decision tree → bad impact on instruction cache
- EPDT_22c improves current state-of-the-art\(^1\)

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