**Problem and Motivations**

Segmentation is crucial for high-level vision. It remains challenging due to visual ambiguity and variety.

- **Observations**
  - Different methods behave differently.
  - Each method gives different results under different parameters.

- **Motivations**
  - Combine complementary information to improve performance.
  - Capture visual patterns using superpixels generated by different methods with varying parameters.

**Superpixel Aggregation and Bipartite Graph Partitioning**

- Combine pixels and multiple/multi-scale segmentations by a bipartite structure. Using superpixels as grouping cues:
  - Pixels in a superpixel tend to belong together.
  - Similar neighboring superpixels tend to belong together.

**Algorithm 1 Transfer Cuts**

Input: A bipartite graph $G = \{X, Y, B\}$ and a number $k$. Output: A $k$-way partition of $G$.

1. Form $D_X = \text{diag}(B_1)$, $D_Y = \text{diag}(B^T_1)$, $W_X = B^T_1 D^{-1}_Y B_1$, and $L_X = D_X - W_X$.
2. Compute the bottom $k$ eigenvectors $(\lambda_i, v_i)^T$ of $L_X$.
3. Obtain $v_i$ such that $0 \leq v_i < 1$ and $v_i \geq v_i - 1$, $i = 1, \ldots, k$.
4. Compute $f_1 = (v_1, \ldots, v_k)^T$, with $u_i = \frac{1}{\lambda_i} v_i^T D_X v_i$.
5. Derive $k$ groups of $X \cup Y$ from $f_1, \ldots, f_k$.

**Speedup by the bipartite structure**

- $(1, MS)$ $(2, MS)$ $(3, MS)$: $4.11$ s for generating superpixels and $0.65$ s for Tcut.

**Algorithm 2 Segmentation by Aggregating Superpixels**

Input: An image $I$ and the number of segments $k$. Output: A $k$-way segmentation of $I$.

1. Collect a bag of superpixels $S$ for $I$.
2. Construct a bipartite graph $G = \{X, Y, B\}$ with $X = I \cup S$, $Y = S$, and $B$ defined in (1-3).
3. Apply Tcut in Algorithm 1 to derive $k$ groups of $G$.
4. Treat pixels from the same group as a segment.

SAS takes $6.44$ s per image of size $481 \times 321$, where $4.11$ s for generating superpixels and $0.65$ s for Tcut. MNcut, MLSS, Ncut and TBES take more than $30$, $40$, $150$, and $500$ s, respectively. Codes of SAS are available at: www.ee.columbia.edu/dvmm.

**Segmentation Results**

- **Results on Berkeley segmentation database (BSDS)**
  - Methods: PRI, Vol, GCE, BDE
  - PRI: Probabilistic Rand Index; Vol: Variation of Information; GCE: Global Consistency Error; BDE: Boundary Displacement Error.
  - PRI: 0.906, 0.813, 0.818, 0.821, 0.818, 0.813, 0.818, 0.813
  - Vol: 0.857, 0.857, 0.857, 0.857, 0.857, 0.857, 0.857, 0.857
  - GCE: 0.200, 0.200, 0.200, 0.200, 0.200, 0.200, 0.200, 0.200

- **Sensitivity of SAS w.r.t. the parameters**
  - Input: 3D MS&FH: use three over-segmentations from each method.
  - Output: 3D MS&FH: take $6.44$ s per image.