Summary of Semantic Color Reduction Methods

1. Mathematical Foundation

Semantic labels (e.g., "urban daytime", "character green") are represented as functions over the Lab color space.

Each semantic corresponds to a function f_semantic(L, a, b) whose domain is inferred from a set of representative Lab points.

Modeling methods include:

- Convex hull
- Gaussian Mixture Models (GMM)
- Kernel Density Estimation (KDE)
- k-Nearest Neighbors

2. Semantic Overlap Detection

Multiple semantic domains can coexist in Lab space. Their overlap can be measured by:

- Shared support: regions where f_i > 0 and f_j > 0
- Probability overlap: Bhattacharyya distance or minimum value integrals

3. Initial Semantic Region Assignment

For downscaled images:

- Random pixel selection and Lab noise application
- Influence from surrounding labeled pixels
- Mapping to the smallest enclosing semantic region

This Monte Carlo process is repeated with decreasing noise until all pixels are labeled.

4. Semantic Denoising

Small disconnected regions are treated as semantic noise:

- Connected components smaller than a threshold S_n

- Absorbed into the most frequent neighboring semantic region

5. Implementation Readiness

With semantic functions, probabilistic initialization, and morphological cleanup,

a semantic-aware dithering system can be implemented.

Note:

Semantic functions coexist in Lab space but are exclusive in image space.

The system minimizes semantic energy via probabilistic labeling and local attraction.