Simple Linear Iterative Clustering (SLIC)

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Outline

1. Scene Modeling
   MGRSS
   Segmentation

2. SLIC Algorithm
   Introduction

3. Conclusion
   Summary
   Future Work
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MGRSS

Goals

Identify explosive hazards
- Increase probability of detection
- Decrease false alarm rate

Markov Ground Region Segmentation System (MGRSS)
- Represent the ground as scene
- Create a scene model from ground penetrating radar (GPR) data
- Track objects found in the scene
Objects of interest within the scene:

- Ground layer
- Sub-surface layers
- Explosive (landmine) objects
- Non-explosive (clutter) objects
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MGRSS places the scene within a MRF and segments GPR scenes into three-dimensional regions. By over-segmenting the scene:

- Super-voxel regions are labeled
- These regions are nodes in the MRF
- Drawing inference from the reduced MRF is more efficient
GPR Image
Graph-Based Segmentation
SLIC Segmentation
Introduction

- http://ivrl.epfl.ch/research/superpixels
- Adaptation of $k$-means clustering
- Weighted distance measure $D$
  - Color images in CIE $L^*a^*b^*$ space
  - Spatial proximity: $x$, $y$, $z$ coordinates
  - $z = 1$ segments super-pixel regions
- Search limited to super-voxel size area around cluster center
- Controlled size and compactness of super-voxels
Introduction

Parameters to note, $k$, $m$, and $N$.

$k$
- is the only input parameter
- defines the number of clusters

$N$
- the number of pixels

$m$
- is a constant in the distance measure
- influences compactness of super-voxels
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Points are represented by:

\[ C_i = [l_i \ a_i \ b_i \ x_i \ y_i \ z_i]^T \] (1)

The cluster size, \( S \), is:

\[ S = \sqrt{N/k} \] (2)
Cluster centers are taken from the lowest gradient position in a $3 \times 3 \times 3$ neighborhood.

Spatial extend of a super-voxel region is $S \times S \times S$.

The pixel search region is $2S \times 2S \times 2S$. 
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Points are assigned to clusters by finding the nearest cluster center.

Cluster centers are updated to the mean vector \([l \ a \ b \ x \ y \ z]^T\) of the cluster points.

\(E\) is the residual error from new cluster centers to their previous center. It is calculated using the \(L_2\) norm.

The assignment and update steps are repeated until the error converges. In practice, 10 iterates were found to be satisfactory.

Post-processing assigns any disjoint pixels to the nearest super-voxel.
The distance measure $D$ is composed of:

- color space $[l \ a \ b]^T$
- voxel position $[x \ y \ z]^T$

The range of the color space is defined, while the voxel positioning varies based upon image size.

- Placing greater weight on spatial distance creates larger super-voxels.
- Placing greater weight on color emphasizes non-spatial features and creates smaller super-voxels.
Process

Normalizing Color and Spatial Proximity within $D$

- $d_c$ is the color distance
- $N_c$ is the max color distance
- $d_s$ is the spatial distance
- $N_s$ is the max spatial distance
Process

Normalizing Color and Spatial Proximity within $D$

\[ d_c = \sqrt{(l_j - l_i)^2 + (a_j - a_i)^2 + (b_j - b_i)^2} \]  

(3)

\[ d_s = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2 + (z_j - z_i)^2} \]  

(4)

\[ D' = \sqrt{\left(\frac{d_c}{N_c}\right)^2 + \left(\frac{d_s}{N_s}\right)^2} \]  

(5)
Process

Normalizing Color and Spatial Proximity within $D$

Maximum spatial distance is given by $N_s = S = \sqrt{N/k}$.

$N_c$ will be more variable, but when fixed to a constant $m$:

$$D' = \sqrt{\left(\frac{d_c}{m}\right)^2 + \left(\frac{d_s}{S}\right)^2} = \sqrt{(d_c)^2 + \left(\frac{d_s}{S}\right)^2 m^2}$$

(6)

As $m$ increases spatial priority increases and clusters are more compact. Decreasing $m$ tightens boundaries, i.e. the color distance has greater emphasis, and clusters have less regularized size and shape.
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Summary

- Have not yet incorporated into MGRSS
- Super-pixels appear more structured than GB
Future Work

- Incorporate SLIC into MGRSS
- Compare to GB and EHGB (super-voxels)
- Learn parameter weights for MRF