Multi-Frame Dim Target Detection Using 3D Multiscale Geometric Analysis

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3D Beamlet Transform (Donoho and Levi)

Construction of 3D Beamlets
- 3D Beamlets is a strategic compact set of line segments
- The cardinality of the beamlet set is $O(n^4)$
- Every smooth path in the image can be approximated by a short chain of beamlets

1. Mark vertices on the Boundary of dyadic cubes
2. Connect marked vertex pairs in every dyadic cube

Beamlet-Based Algorithms
- **First level algorithms** – mostly based on thresholding of beamlet coefficients.
- **Second level algorithms** - based on the tree structure of dyadic cubes.
- **Third level algorithms** - based on the neighboringness of beamlet coefficients according to the beamlet graph.

Beamlet Transform

Definitions:
- Beamlet Transform: $T_f(b) = f(\gamma_b) \mu_b$, $b \in B_i$
- Beamlet Coefficients: $\{f(\gamma_b) \mu_b\}$

Beamlet Transform stands for the integral transform of the 3D image over the multiscale set ($B_i$)

Beamlet coefficient stands for the linear integral of the 3D image over the corresponding beamlet.

Beamlet-Based Graphs

- **Beamlet Graph**: Vertices: Voxel corners
  Edges: Beamlets
- **Good-Continuation Graph (GCG)**: Vertices: Beamlets
  Edges: Two beamlets connected by edge if they satisfy 'Good Continuation' relation.

Illustrative example of a first level algorithm

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Multi-Frame Dim Target Detection in Synthetic Scenes

Multi-Frame Dim Target Detection in Real Scenes

Using back projection based whitening for successful detection in real scenes

**General Description**:
1) Find beamlet projections with high count of peaks.
2) Apply binary back-projection on the peak coefficients.
3) Use the result image as penalty function for the original image.
4) Apply MFD algorithm with the resulting image.

False Alarms in Real Scenes

Notes:
Only beamlets with non-zero coefficients are used to construct GCG. Beamlet center of mass used for node location only for illustrative purposes.