Consistent normal orientations are essential for renderings and many processing algorithms. Given a point cloud with unordered normals, we re-orient the normals in a consistent way.

Key points of our work:
- Consolidation of previous work into a Markov Random Field model
- Globally optimal solution of the MRF
- Out-of-core framework for large point clouds

Problem formalization

Every point \( p_i \) with normal \( n_i \) is assigned a label \( l \in \{-1, 1, \emptyset\} \), such that the adapted normals \( v_i := n_i \) are most consistent. Consistency is measured upon a neighbor graph with edges \( \varepsilon \) and the flip criterion \( \psi : \varepsilon \to \{0, 1\} \) (positive for consistent edges, negative for non-consistent edges). Hopper’s flip criterion [1] can be expressed as:

\[
\Phi_{\text{Hopper}}(v_i) = (n_i, n_j)
\]

Example graph:

The following potentials are derived from this flip criterion:

\[
E_r(l_i, l_j) = \begin{cases} 0 & |\psi(l_i, l_j) - 0| \geq 1 \\lor l_i = l_j \\lor n_i \cdot n_j = +1 \\ 1 - \Delta \delta(n_i, n_j) & \text{otherwise} \end{cases}
\]

This potential definition can be visualized as follows:

The sum of potentials forms a labeling’s energy. The optimal orientation is the energy’s minimizer:

\[
E(L) = \sum_{(i,j) \in \varepsilon} E_r(l_i, l_j)
\]

The nearby sections give an overview of various ways to solve this equation.

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