Graph Cuts Optimization for Multi-Limb Human Segmentation in Depth Maps

Abstract

We present a generic framework for object segmentation using depth maps based on Random Forest and Graph-cuts theory, and apply it to the segmentation of human limbs in depth maps. First, from a set of random depth features, Random Forest is used to infer a set of label probabilities for each data sample. This vector of probabilities is used as unary term in parallel Graph-cuts algorithm. Moreover, depth of spatio-temporal neighboring data points are used as boundary potentials. Results on a new multi-label human depth data set show high performance in terms of segmentation overlapping of the novel methodology compared to classical approaches.

Random Forests

1. Feature extraction: depth offsets

\[ f_\theta(x) = d_{\theta}(x) u(x) + v(x) \]

2. Tree splitting

\[ Q_\theta(x) = \frac{(x, y) f_\theta(x, y) < \tau, \phi = (\theta, \tau)}{Q \setminus Q_{\theta, \tau}} \]

3. Splitting criteria

\[ \phi = \arg \max_{\phi \in \Phi} GQ(\phi) \]

4. Leaf probability distribution

\[ P(x) = \frac{1}{T} \sum_{t=1}^{T} P_t(x) \]

Graph-cuts

Energy Function

\[ E(L) = U(L) + \lambda B(L) \]

1. Unary Potential

\[ U_i(L_i) = -\ln(P(c|I, x)) \]

2. Pairwise Potential

\[ B(L) = \sum_{(i, j) \in E} B(i, j) \Omega(L_i, L_j) \]

(a) Boundary term

\[ B(i, j) = \frac{1}{\dist(i, j)} e^{-|\mathbf{x}_i - \mathbf{x}_j|^2} \]

(b) Label cost term

\[ \Omega(L_i, L_j) = \begin{cases} 0 & \text{for } L_i = L_j \\ 10 & \text{for } L_i = RU, L_j = RU \\ 5 & \text{for } L_i = LH, L_j = LH \\ 1 & \text{otherwise} \end{cases} \]

5. Results

Segmentation accuracy (%)

<table>
<thead>
<tr>
<th>Method</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GT</td>
<td>75</td>
</tr>
<tr>
<td>RF</td>
<td>80</td>
</tr>
<tr>
<td>FbF-GC</td>
<td>85</td>
</tr>
<tr>
<td>Ours</td>
<td>90</td>
</tr>
</tbody>
</table>

Human Limbs from RGBD Dataset

- Video recordings using Kinect
- 3 sessions, 2 actors
- 500 frames in total
- 640x480 images
- RGB
- Depth
- Ground-truth labels
- L/R hands
- L/R upper limbs
- L/R lower limbs
- Torso

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