Parallel Graph-Based Hierarchical Video Segmentation

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Motivation

1. It takes too much time to finish segmentation in practice.

2. Previous approaches cannot store spatio-temporal information [1].

Graph-Based segmentation

\[
\text{Int } R := \max_{e \in \text{MST}(R)} w(e) \quad (1)
\]

Int(R): the internal variation of a region R, the maximum edge weight \( e_{\text{max}} \) of its Minimum Spanning Tree (MST).

\( w(e) \): the edge weight of e. \([2]\)

\[
R\text{Int}(R) := \text{Int}(R) + \delta(R), \text{ with } \delta(R) := \frac{\tau}{|R|} \quad (2)
\]

|\( |R| \): size of region R in pixels
\( \tau \): a constant parameter. \([2]\)

Merge condition: whether the edge weight (normalized color difference) is less than the internal variation of both regions incident to the edge

\[\text{Int}(R) := \max_{e \in \text{MST}(R)} w(e) \]

\[R\text{Int}(R) := \text{Int}(R) + \delta(R), \text{ with } \delta(R) := \frac{\tau}{|R|}\]

Graph-Based Hierarchical segmentation

1. begin segmentation with $\tau \sim 0.02$ to obtain an over-segmentation
2. compute a descriptor for each region in form of its Lab histogram
3. choose the difference between two histograms as edge weight
4. segment the initial set of over-segmented regions into super-regions
5. compute a hierarchy or a bottom-up tree of regions
6. construct a graph in 3D space-time [4]

Graph-Based Hierarchical Segmentation

Test image

Level 0

Level 10

Level 20

Algorithm 1 (without spatio-temporal information in over-segmentation):
Input: A video-clip set $A = \{im1, im2, \ldots, im8\}$
Output: The video segmentation images in the set
1. read images (video clips)
2. set up hierarchy
3. smooth images
4. build edges for all 8 images
5. build nodes for 8 images together
6. divide 8 images into 8 groups
7. construct edges based on 8-neighborhood every group
8. segment graph for each group in parallel
9. assign over-segmentation information to level 0
10. hierarchical segmentation
11. generate output
Parallel GBH video segmentation without spatio-temporal information in over-segmentation

Test image

Level 0

Level 5

Level 10

Level 15

Level 20
Algorithm 2 (with spatio-temporal information in over-segmentation):
Input: A video-clip set $A = \{im1, im2, \ldots, im80\}$
Output: The video segmentation images in the set
1. read images (video clips)
2. set up hierarchy
3. smooth images
4. build edges for all 80 images
5. build nodes for 80 images together
6. divide 80 images into 8 groups
7. construct edges based on 26-neighborhood every group
8. segment graph for each group in parallel
9. assign over-segmentation information to level 0
10. hierarchical segmentation
11. generate output
Parallel GBH video segmentation with spatio-temporal information in over-segmentation

<table>
<thead>
<tr>
<th>Test image</th>
<th>Level 0</th>
<th>Level 5</th>
<th>Level 10</th>
<th>Level 15</th>
<th>Level 20</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Test image" /></td>
<td><img src="image2" alt="Level 0" /></td>
<td><img src="image3" alt="Level 5" /></td>
<td><img src="image4" alt="Level 10" /></td>
<td><img src="image5" alt="Level 15" /></td>
<td><img src="image6" alt="Level 20" /></td>
</tr>
</tbody>
</table>
## Experimental Result

<table>
<thead>
<tr>
<th>Method</th>
<th>8 clips</th>
<th>Method</th>
<th>80 clips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parallel GBH without spatio-temporal information in over-segmentation</td>
<td>6 – 7 s</td>
<td>Parallel GBH with spatio-temporal information in over-segmentation</td>
<td>150 - 156 s</td>
</tr>
</tbody>
</table>

Parallel GBH speed comparison

Parallel GBH without spatio-temporal information in over-segmentation

Parallel GBH with spatio-temporal information in over-segmentation
3D Segmentation Accuracy (3D ACCU)

1. This metric measures what fraction of a ground-truth segment is correctly classified by the Supervoxel: each super-voxel should overlap with only one object/segment as a desired property.
2. run the algorithm for all videos multiple times in a data set provided by Chen[6]

Future Work

- Optimize data parallelism
- Implement with different parallel library
- Implement the new algorithm on different platform
Conclusion

• We propose a novel approach to segment video clips in parallel which achieves a high-quality, hierarchical segmentation.
• We have implemented our algorithm with OpenMP and runs about 3 times faster than the sequential Graph-Based hierarchical video segmentation.
• Our implementation doesn't depend on programming tricks.

Acknowledgement This work was completely implemented in the Vision and Perceptual Machines Lab (VPML).
Thank You

Q&A