Segment-Tree Based Cost Aggregation for Stereo Matching with Enhanced Segmentation Advantage

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I. Introduction

Segment-tree (ST) based cost aggregation algorithm [1] successfully integrates the information of segmentation with non-local cost aggregation framework. However, the original strategy performs unreasonable, so we propose a novel segmentation algorithm for constructing a more faithful ST with enhanced segmentation advantage according to a robust initial over-segmentation. Then we implement non-local cost aggregation framework on this new ST structure and obtain improved disparity maps. Performance evaluations on all *31* Middlebury stereo pairs show that the our algorithm outperforms than other *five* state-of-the-art algorithms and also keeps time efficiency.

II. Proposed Algorithm

For the original ST based stereo matching algorithm, the tree structure is represented by :

$$\omega_{e_j} \le \min(Int(T_p) + \frac{k}{|T_p|}, Int(T_q) + \frac{k}{|T_q|}) \quad (1)$$

However, in formula (1) the original segmentation algorithm generally performs underwhelming for the following reasons:

1) Large k leads to a much relaxed threshold at the beginning of *grouping* and performs under-segmentation regions with inconsistent boundaries.

2) Small k performs better at the beginning of *grouping* but inevitably leads to consistent over-segmentation and too many boundaries.

3) As the region size $|T|$ grows, $k/|T|$ decreases dramatically which becomes increasingly unreliable for discriminating between regions of the same type.

4) When $|T|$ increases, the connecting decision function would perform much too constrained. It will break the homogeneous regions into different segments and contrary to the disparity consistency assumption.

More importantly, while implementing non-local cost aggregation on this imperfect ST structure would lead the substandard utilization of segmentation advantage.

Based on these reasons, an algorithm is proposed for constructing a new ST structure by us. The connected decision function can be formulated as follows:

$$\omega_{e_j} \le \min(Int(T_p) + k \cdot \sqrt{|T_p|}, Int(T_q) + k \cdot \sqrt{|T_q|}) \quad (2)$$

Here we choose k as *0.02*. We perform it mainly on the following considerations:

1) It begins with a more constrained threshold while *grouping*. The choice of k keeps most of the boundaries are coincident with true region borders.

2) When $|T|$ increases, the proposed segmentation algorithm performs a more relaxed threshold. It could enforce more similar regions merged and perform more compatible with disparity consistency assumption.

With formula (2), an Improved-ST (IST) based non-local cost aggregation algorithm for stereo matching can be implemented, which is descripted :

Alogrithm1 *Improved-ST Algorithm*

for *each* $p \in I$
  for $d \in$ *[0,maxdis]*
    Compute Matching cost with method of [2]
  end for
end for
Compute D by ***ST*** *based algorithm with formula (2)*
  Construct updated ***ST*** *with Color-Depth weight:*

$$\omega(s,r) = \lambda \frac{|I(s) - I(r)|}{\Delta_I} + (1-\lambda) \frac{|D(s) - D(r)|}{\Delta_D}$$

Aggregate costs and get D_1 *as updated result*

III. Experimental Results

Performance Evaluations on all 31 Middlebury Stereo Pairs in non-occluded Regions without Disparity Refinement

Algorithms	CS-GF	MST	ST-2	CS-MST	CS-ST	IST-2
Avg. Error(non-occ)	9.15	10.67	10.25	11.05	10.27	7.07
Avg. Time(s)	7.67	0.56	0.87	1.69	1.64	1.33

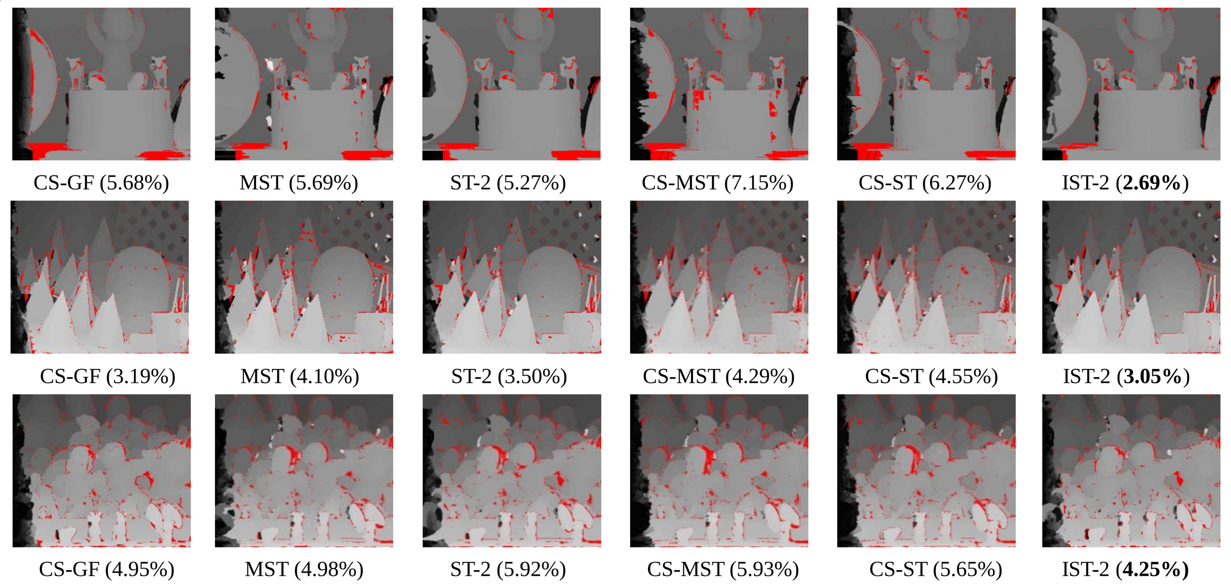

Fig.1. Results of *Baby3,Cones and Dolls* by *six* algorithms without Disparity refinement.

Performance Evaluations on all 31 Middlebury Stereo Pairs in non-occluded Regions with Disparity Refinement

Algorithms	CS-GF	MST	ST-2	CS-MST	CS-ST	IST-2
Avg. Error(non-occ)	8.46	9.83	9.42	9.93	8.40	6.52
Avg. Error(all)	15.77	16.98	18.32	17.71	16.31	13.78
Avg. Time(s)	9.10	0.75	1.12	3.38	3.27	1.45

IV. Conclusion

We improved the ST based stereo algorithm by using a novel segmentation algorithm. Firstly, it provides an enhanced segmentation advantage and constructs a more faithful ST structure. Secondly, it also better meets the disparity consistency assumption. Based on this new tree structure, an Improved Segment-tree (IST) non-local cost aggregation algorithm can be performed. Performance evaluations show that the proposed algorithm outperforms than other *five* aggregated based algorithms on all *31* Middlebury stereo pairs and time consuming does not increase too much.

V. Reference

[1]. X.Mei, X.Sun and W.Dong et al., "Segment-Tree based Cost Aggregation for Stereo Matching," *In IEEE CVPR, 2013, pp. 313-320.*

[2]. P.Yao, H.Zhang and Y.Xue *et al.*, "Iterative Color-Depth MST Cost Aggregation for Stereo Matching," *In IEEE ICME, 2016, pp.1-6.*