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Interactive RGB-D Image Segmentation Using Hierarchical Graph Cut and Geodesic Distance

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Outline

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- Introduction
- HGG Segmentation Method
- Experiments
- Conclusion

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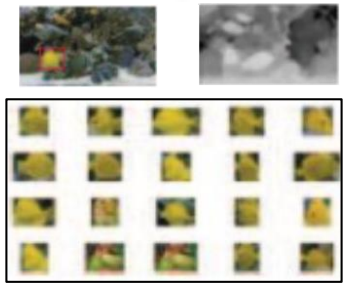
Introduction of RGB-D Image Segmentation

RGB-D Image Segmentation

- Image segmentation plays a foundational role in various applications of RGB-D images

salient object detection



object retrieval

retargeting

refocusing

Why RGB-D Image Segmentation is Different?

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- Depth brings more information in discriminating objects from background, but it has different characteristics to color

How to measure color and depth similarities in a combined framework but with different strategy?

- Depth causes the extra computational cost

How to reduce computational cost in RGB-D segmentation , especially in the situations with high efficiency requirements?

Our Work

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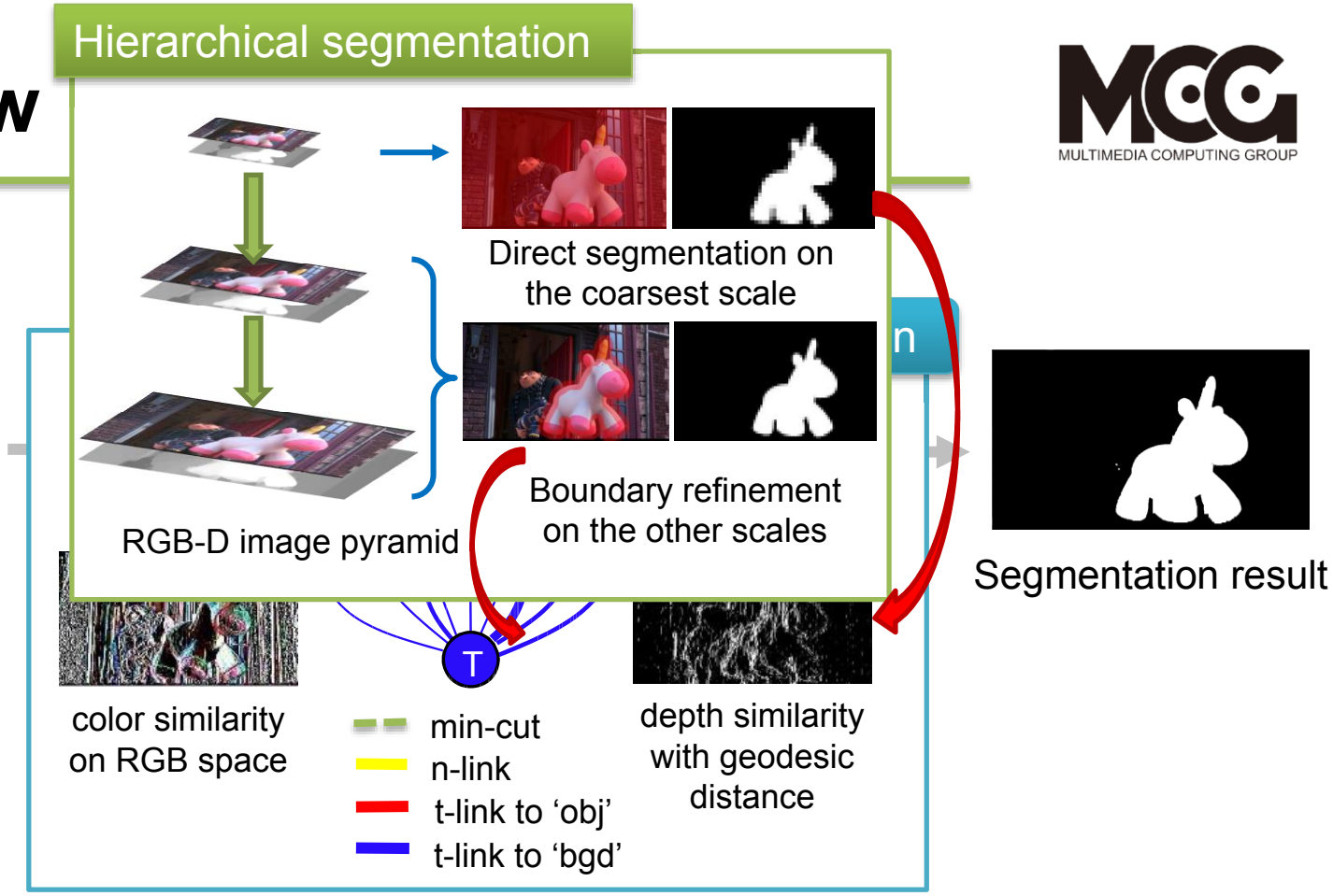
- Propose a novel RGB-D image segmentation method
  - Utilize Euclidean distance for color similarity measurement and geodesic distance for depth similarity measurement, and combine them in graph cut method
  - Hierarchically segment RGB-D image on image pyramid by only processing the boundary regions based on the initial segmentation result

HGG Segmentation Method: Hierarchical Graph Cut with Geodesic Distance

Overview

RGB-D image with manual labels

- foreground
- background



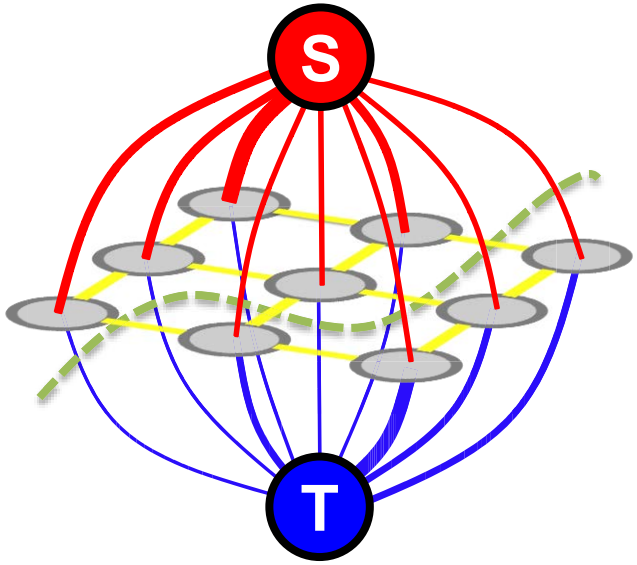
GG Segmentation

- **Preliminary**: Graph Cut
  - Objective function

$$E(L) = \lambda R(L) + B(L)$$

region boundary

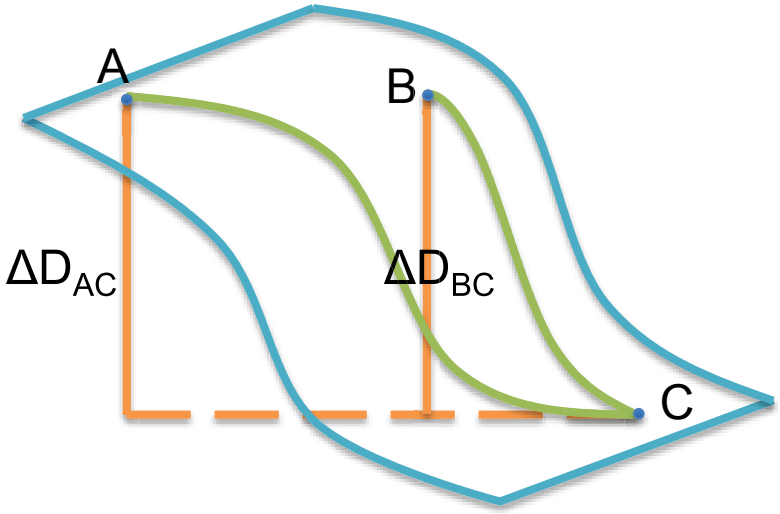
  - Procedure
    - Generate the terminal nodes of foreground and background
    - Measure the similarity of each pixel to source node S and sink node T
    - Calculate the gradients between adjacent pixels
    - Obtain min-cut by optimization



Color and Depth Similarity

- Color similarity
  - Euclidean distance of color space

- Depth similarity
  - Geodesic distance



Depth difference

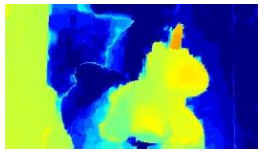
$\Delta D_{BC} = \Delta D_{AC}$

Geodesic distance

$G(A, C) \neq G(B, C)$

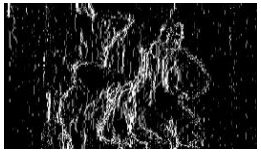
Regional and Boundary Penalty


foreground similarity of color

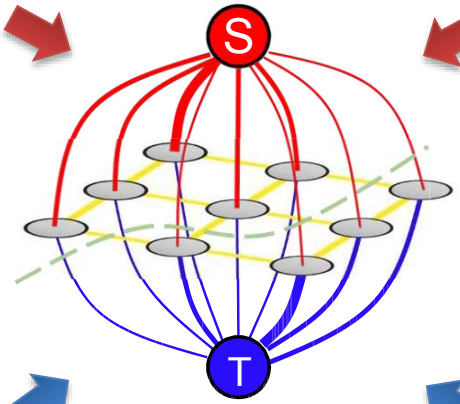


foreground similarity of depth

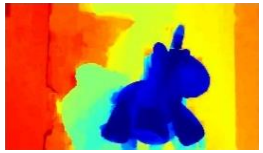
color gradient



depth gradient



background similarity of color



background similarity of depth

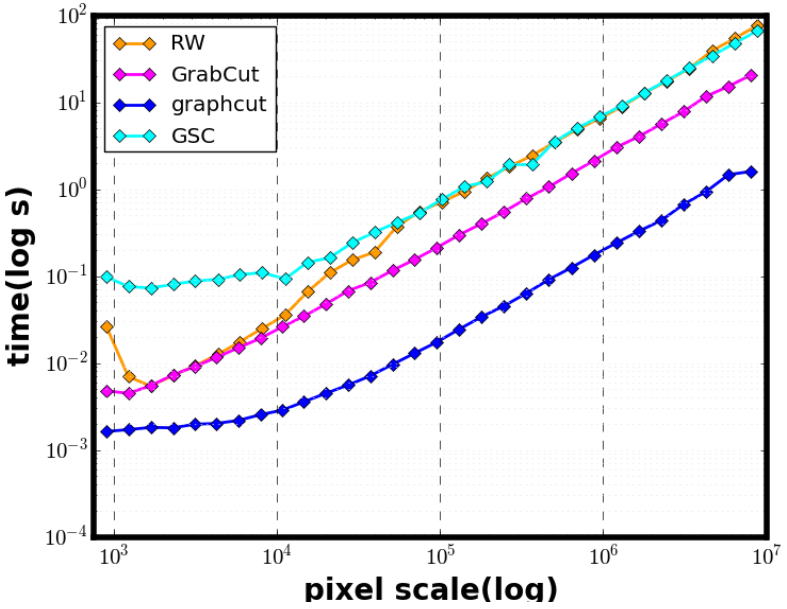
$$E(L) = \lambda \underbrace{R(L)}_{\text{depth}} + \underbrace{B(L)}_{\text{depth}}$$

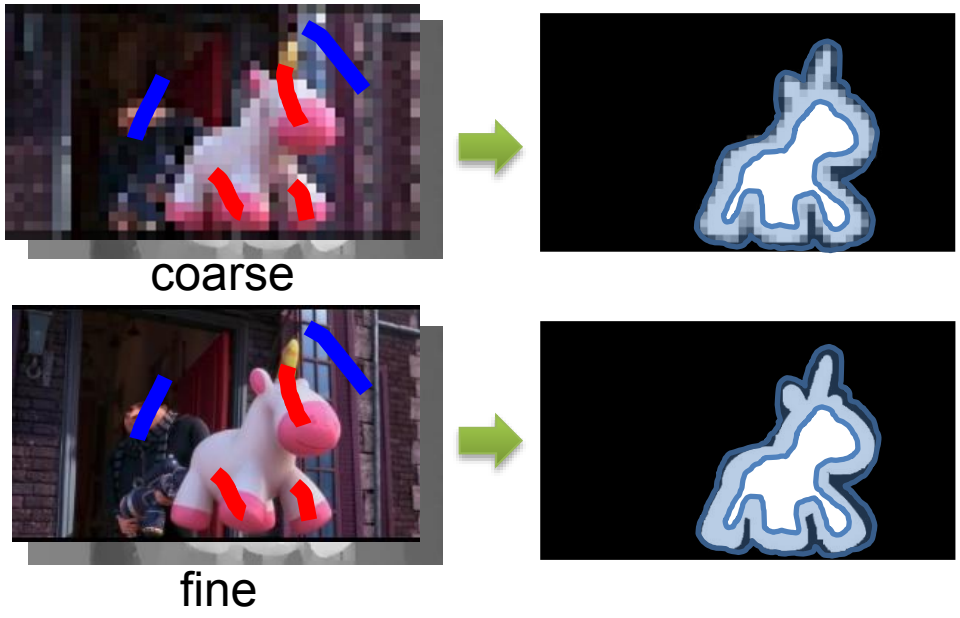
color

color

Observation

- Computational cost increases rapidly when image resolution increases
- The segmentation results on different image scales have similar appearance, and difference only occurs on boundary precision

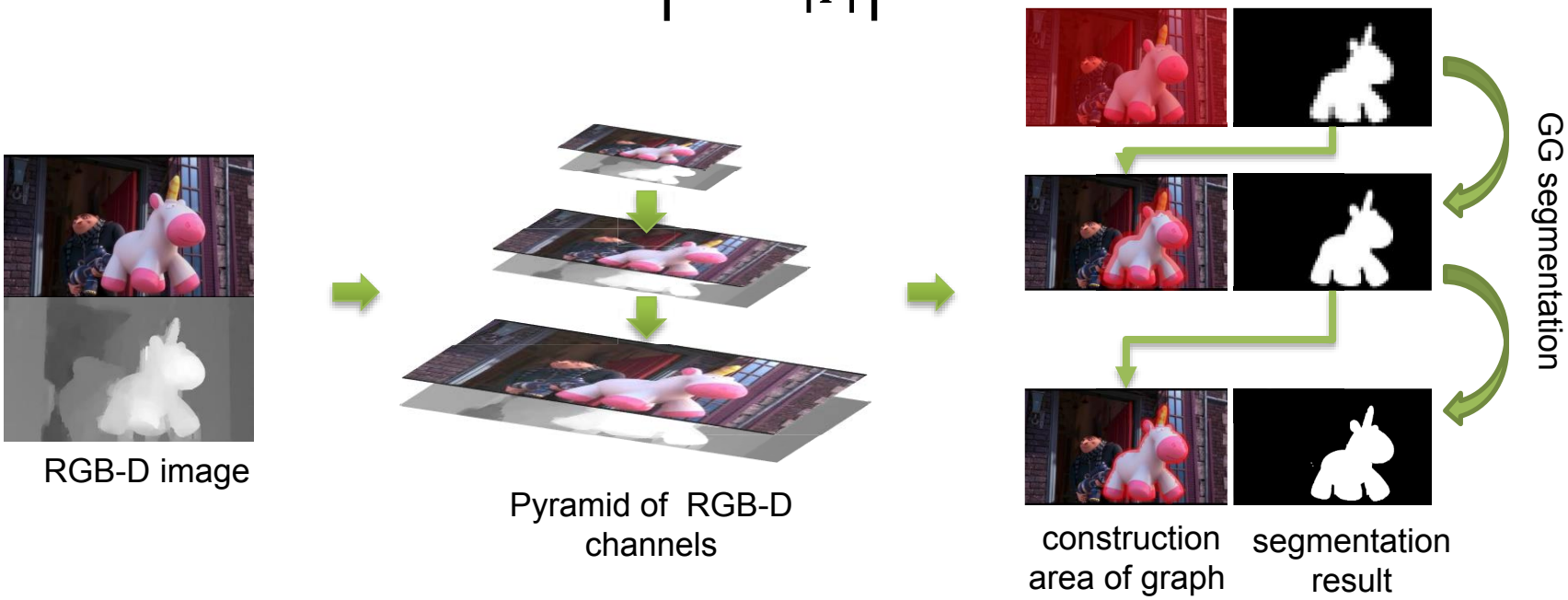




Hierarchical Segmentation

- Construct a scale space $\{I_0, I_1, \ldots, I_n\}$ for each RGB-D image I

$$n = \left\lceil \log_\rho \frac{\varphi}{|I|} \right\rceil$$



Experimental Results

Dataset and Experimental Settings

- Dataset
  - NJU400: 400 stereo image pairs
  - RGBD Benchmark: 1,000 RGB-D images

- Platform
  - PC with a four-core 3.40 GHz CPU and 8GB memory

Methods for Comparison

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- GC: Graph Cut [ICCV, 2001]
- GB: Grabcut [TOG, 2004]
- MGC: Hierarchical Graph Cut [ICCV, 2005]
- GDD: Only depth with geodesic distance
- RGBD: Using depth as the fourth channel [SSVM, 2015]
- GG: Our method without hierarchical strategy
- HGG: Our method with hierarchical strategy

Comparison

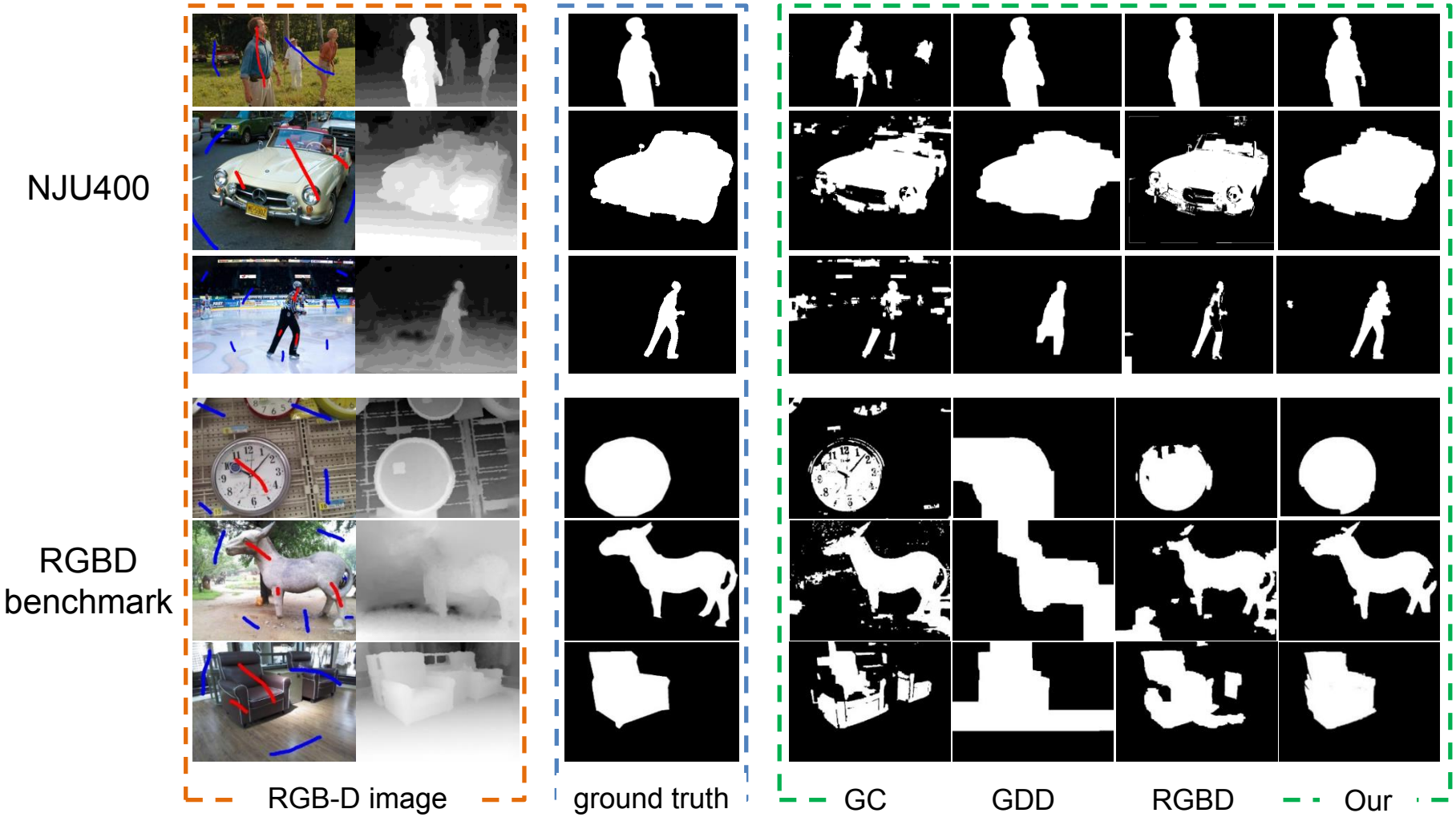
- Effectiveness comparison
  - Criteria: Precision, recall, F-measure (beta = 0.3)

	GC	GB	MGC	GDD	RGBD	GG	HGG
precision	0.7163	**0.9361**	0.7575	0.8542	0.8419	**0.9272**	0.8946
recall	0.7254	0.5558	0.7360	0.8921	0.7796	**0.9032**	**0.9287**
F_β	0.7184	0.8084	0.7524	0.8627	0.8267	**0.9215**	**0.9022**

- Efficiency comparison
  - Execute each method 10 times to obtain its average running time of segmentation

	GC	GB	MGC	GDD	RGBD	GG	HGG
Time(s)	0.4340	5.6015	**0.0828**	32.0488	0.3423	32.2416	**0.1131**

Examples of Comparison



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Conclusion

Conclusion

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- Contribution
  - Propose a novel interactive segmentation method for RGB-D images
  - Combine different similarity measurement strategies on color and depth to improve segmentation effectiveness
  - Utilize hierarchical strategy to improve segmentation efficiency

- Future work
  - Further explore the potential of depth for RGB-D image segmentation
  - Apply the proposed method in various applications of RGB-D images

Thank you

Q&A