Segmenting a Low-Depth-of-Field Image Using Morphological Filters and Region Merging

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Outline

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Definition of Low-Depth-of-Field(DOF)

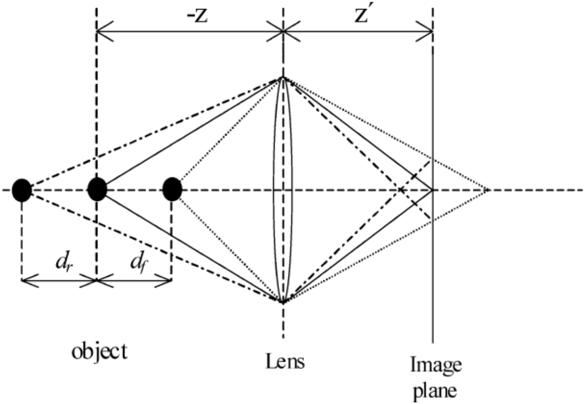

Figure 1: Optical geometry of a typical camera.

Examples of Low DOF Images

Figure 2: Low-DOF images.

Examples of Low DOF Images

Figure 3: A color image.

Outline

Task Description

Partion an image with low depth-of-field (DOF) into focused object-of-interest (OOI) and defocused background.

Figure 4: Original Low-DOF image

Figure 5: Focused OOI

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Related Works

Two approaches to segmentation of low-DOF images:

- Edge-based approaches
  - extract boundary of the object by measuring the amount of defocus at each edge pixel.
  - defect: fail to detect boundary edges of the natural object.
- Region-based approaches
  - exploit high frequency areas in the image.
  - defect: high-frequency components in defocused regions and nearly constant gray levels in focused regions.

Examples of errors

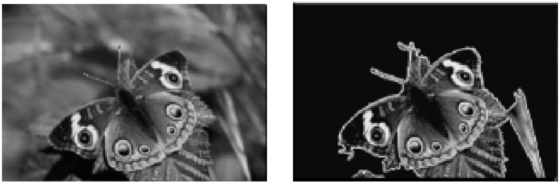

Figure 6: An example of error

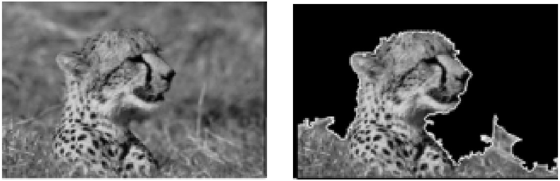

Figure 7: An example of error

Methodology

Proposed algorithm:

- **step 1**: Feature space transformation using HOS (higher order statistics)
- **step 2**: Morphological filtering by reconstruction
- **step 3**: Region merging and adaptive thresholding

Outline

Feature Space Transformation Using HOS

HOS (Higher Order of Statistics) can suppress Gaussian noise and preserve some of the non-Gaussian information. The fourth-order moment:

$$\hat{m}^{(4)}(x,y) = \frac{1}{N_\eta} \sum_{(s,t)\in\eta(x,y)} (I(s,t) - \hat{m}(x,y))^4 \tag{1}$$

HOS map: each pixel is limited to $[0, 255]$

$$HOS(x,y) = min(255, \frac{\hat{m}^{(4)}(x,y)}{DSF}) \tag{2}$$

An example of HOS map

HOS map yields denser and higher values in the focus areas, suppressing noise in the focused regions.

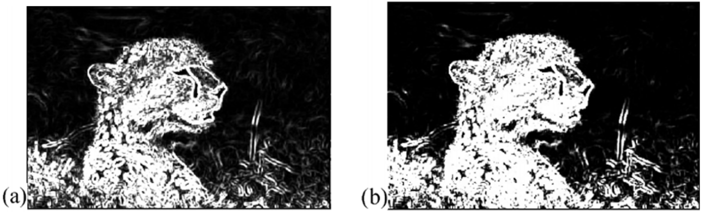

Figure 8: Feature space transformed by (a) local variance (b) higher order statistics.

Notice that small dark and bright patches in focused and defocused regions, respectively.

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1. Introduction
   - Definition of Low-Depth-of-Field(DOF)
   - Task Description
   - Motivation
2. Methodology
   - Feature Space Transformation Using HOS
   - HOS Map Simplification by Morphological Filtering by Reconstruction
   - Region Merging and Adaptive Thresholding
3. Experiments
4. Conclusion

Morphological filtering

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- Disadvantage: do not allow a perfect preservation of contour information.

Proposed morphological operators

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- Opening by reconstruction: $\gamma^{(rec)}(\epsilon_B(O), O)$

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- Opening by reconstruction: $\gamma^{(rec)}(\epsilon_B(O), O)$
- Closing by reconstruction: $\psi^{(rec)}(\delta_B(O), O)$

HOS Map Simplification by proposed morphological operators

Employ morphological closing-opening by reconstruction.

Strength:

- Fills small dark holes
- Removes small bright patches.
- perfectly preserving other components and their contours.

An example of HOS map simplification

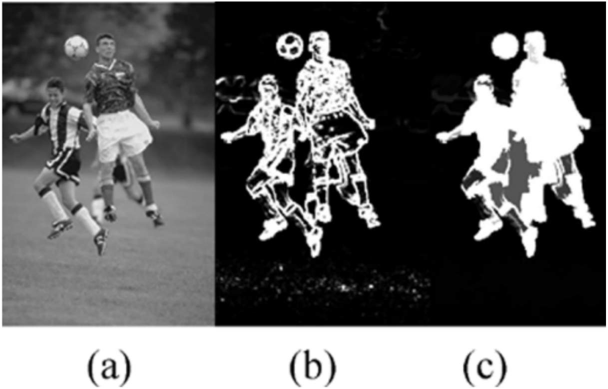

Figure 9: (a) Low-DOF image. (b) HOS map. (c) Simplified image.

Outline

Region Merging

- Typical morphological segmentation techniques: marker extraction and watershed algorithm.
- In this task, extract focused region (OOI) rather than partitioning.

  Suppose OOI of an image is defined as:

$$OOI = \bigcup_{i=1}^{N_{OOI}} = R_i \tag{3}$$

Iteratively assign R_i to OOI or OOI^c based on $\frac{p(nob_i|OOI)}{p(nob_i|OOI^c)}$.

Schematic diagram of Region Merging

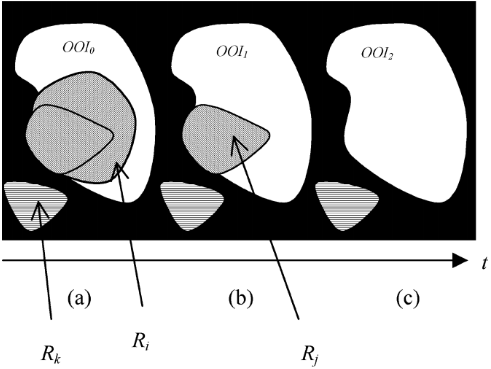

Figure 10: Evolution of *OOI* by the proposed region merging. (a) Initial *OOI* and three uncertain regions with pixel values $(T_L; v_h)$ in the simplified HOS map.(b)R_i is merged into *OOI*. (c) Final *OOI*, after R_j is merged into *OOI*. Note that R_k is not decided as *OOI* since it has a value less than that of OOI_2.

An Example of Region Merging

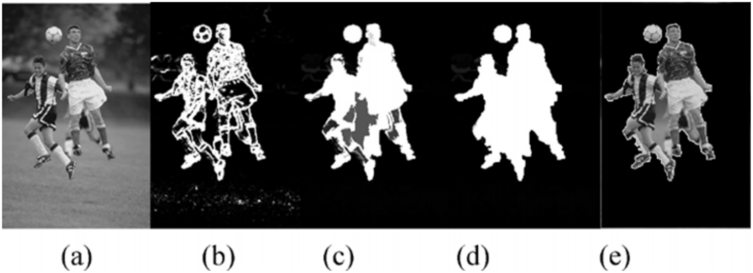

Figure 11: Pictorial illustration of the proposed algorithm. (a) Low-DOF image. (b) HOS map. (c) Simplified image. (d) Region merging. (e) Final decision by thresholding.

Experiment results from each process

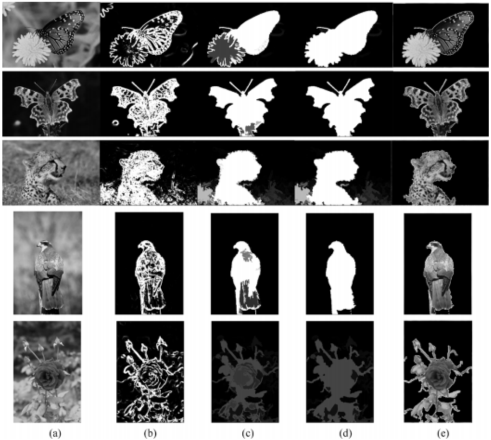

Figure 12: Experimental results from each process. (a) Low-DOF image. (b) HOS map. (c) Simplified image. (d) Region merging. (e) Final decision by thresholding.

Visual Comparison of Segmentation Results

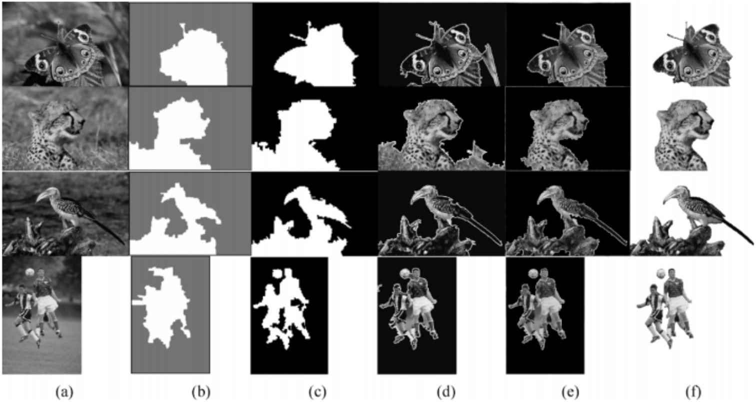

Figure 13: Visual comparison of segmentation results. (a) Low-DOF images. (b) Results from [2]. (c) Results from [8]. (d) Results from [9]. (e) Results from the proposed algorithm. (f) References by human manual segmentation.

Conclusion

Proposed algorithm to extract object-of-image (OOI):

- Transformation using higher order of statistics (HOS)
- Morphological filtering by reconstruction
- Region merging and adaptive thresholding

Bibliography I

Changick Kim.
Segmenting a Low-Depth-of-Field Image Using Morphological Filters and Region Merging.
IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 14, NO. 10, OCTOBER 2005.