Color Image Segmentation-

An Innovative Approach

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Tie Qi Chen, Yi Lu*.

Abstract

- **Color image segmentation**
  - **Color clustering *in a color space***
    - **Fuzzy clustering algorithm**
  - **Color region segmentation *in the image domain***
    - **Three clustering algorithms**

Color Image Segmentation System

❑ Overview of the color image segmentation

CL1

Compute
) histogram
ı color space

Fuzzy clustering
in color histogram domain

CL2

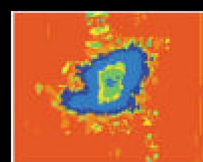
Map initial clusters to image domain

Merging neighboring clusters

CL3

A set of clo
regions

Fuzzy membership function
Color distance function



Color distances between the neighboring regions
Region sizes and maximum number of clusters

Stage 1: Color segmentation

Stage 2: Region segmentation

Fig. 1. An overview of the color image segmentation.

A Fuzzy Clustering Algorithm for Color Segmentation

❑ Color histogram of an image

– ***f(C)*: The number of pixels, *C*: A color in the image**

❑ Fuzzy clustering algorithm

– **Fuzzy set**

  • A cluster of similar colors

– **Fuzzy membership function**

  • The likeness of a color pixel belonging to a fuzzy set

- **Two critical issues involved in a fuzzy membership function**
  - **Generating fuzzy membership functions**
    - The likeness of a data element belonging to a color cluster
  - **Defining a color distance function**
    - Between two color clusters
    - Between a color and a color cluster

❑ Fuzzy membership function

– **Gaussian function**

- The probability if a color C belonging to a color cluster
- $$G_R(C-P) = e^{-\|C-P\|^2/R^2}$$
  - P: The center of the cluster
  - R: The radius of the cluster
- The probability of a color belonging to the k-th cluster and not belonging to any other cluster

Fuzzy membership function
$$H_k(C;\, P_1,\, \cdots,\, P_M) = G_R(C-P_k)\prod_{i\neq k}[1-G_R(C-P_i)]$$

- **Important characteristics of fuzzy membership function**
  - Belief value decreases as the distance between a color *C* and a color cluster *P* increases
  - Belief value of a particular color belonging to a cluster depends on its relationship with other clusters
  - Belief value of a color belonging to a cluster is always greater than zero

– Cluster separability

- How well a given n-cluster description matches a given set of data
- Objective function
  - A mean square error over the inter and intro distances of all color clusters

$$F(P_1,\cdots,P_M)=\sum_{k=1}^{M}\sum_{C_i} f(C_i)\cdot H_k(C_i;P_1,\cdots,P_M)\cdot\left\|C_i-P_k\right\|^2$$

  - Ex) In the case when there is only one cluster (R is radius of cluster)

$$F(P)=\sum_{C_i} d(C_i-P)=\sum_{C_i}\left\|C_i-P\right\|^2\cdot G_R(C_i-P)$$

$\left\|C_i-P\right\|=R$: Large mean square error $\rightarrow$ Largest uncertainty

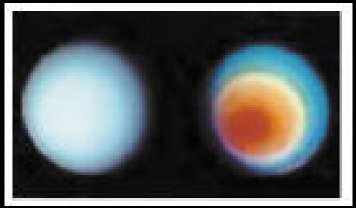
– Optimization process

- C_k : Initial center of cluster 1, t=0, $P_M^0 = C_k$
- $$P_M^{t+1} = \frac{\sum_{C_i} C_i \cdot f(C_i) \cdot H_M(C_i; P_1, \cdots, P_{M-1}, P_M^t)}{\sum_{C_i} f(C_i) \cdot H_M(C_i; P_1, \cdots, P_{M-1}, P_M^t)}$$
- d : The threshold of the difference between a cluster center and the cluster center at the previous iteration
- If $\left\| P_M^t - P_M^{t+1} \right\| > d$, compute a new center
- If $\left\| P_M^t - P_M^{t+1} \right\| \leq d$, accept as the center of the cluster

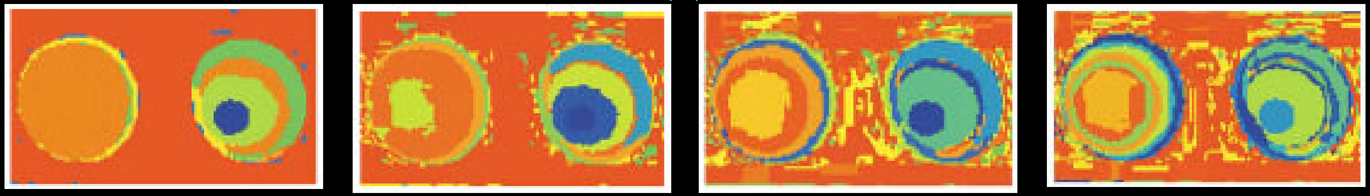
– **Optimization process (Generating a new cluster)**

- $$f(C_k)V(C_k;P_1,\cdots,P_M) \le e\sum_{C_k} f(C_k)$$
- $$V(C;P_1,\cdots,P_M) = \prod_{k=1}^{M}[1 - G_R(C - P_k)]$$
  - The probability of a color not belonging to any existing cluster
- d controls the number of iterations in optimizing a new cluster center
- e determines when to stop generating new clusters
- R is the cluster radius

- **Cluster radius** ***R***
  - **How much the clusters can overlap with each other**
- **Color clustering results**



(a)



(b) (c) (d) (e)

Fig. 2. Color clustering results with different cluster radii on an image with simple features: (a) original image, (b) R=64, (c) R=32, (d) R=16, and (e) R=8.

Image Segmentation in Image Space

❑ Region Segmentation algorithm in image domain

- **Color similarity and spatial adjacency**
- **Important parameters in the image domain**
  - The color distances among neighboring clusters in the spatial domain
  - Cluster sizes
  - The maximum number of clusters in CL3

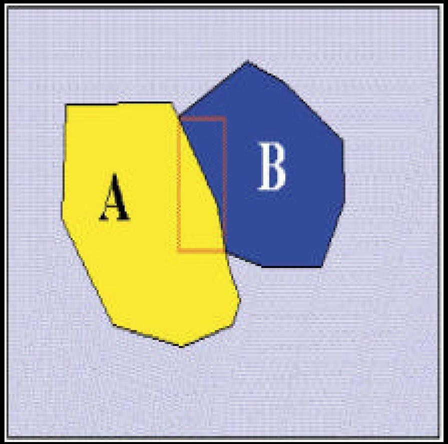
Merging process

- **The order of merging clusters**
- ***Method 1***
  - Merge the neighboring clusters whose color distances are below threshold
    - No consideration of the order of merging
  - Select the smallest cluster and merges the cluster with one of its neighbors to which it has the smallest color distance
- ***Method 2***
  - Selects the smallest cluster and merges the cluster with one of its neighbors to which it has the smallest color distance

- ***Method 3***
  - Repeatedly merges the smallest clusters with the neighbors
  - Selects a pair of two adjacent clusters that has the smallest color distance within the entire image to merge
  - Merges the smallest cluster with its closest neighbor in color distance

❑ Two functions for computing the color distance

- Color difference of the border pixels of clusters A and B
  - $B\_Dist(A,B) = \left| Ave\_B(A) - Ave\_B(B) \right|$



$$Ave\_B(A) = \left\{ \frac{\sum_{(x,y)\in Border(A,B)} f_R(x,y)}{\left|Border(A,B)\right|}, \frac{\sum_{(x,y)\in Border(A,B)} f_G(x,y)}{\left|Border(A,B)\right|}, \frac{\sum_{(x,y)\in Border(A,B)} f_B(x,y)}{\left|Border(A,B)\right|} \right\}$$

2. Illustration of border points between region A and B.

- The central color of a cluster

  - $$\tilde{C}_A = \frac{\sum_{p \in A} C(p)}{|A|}$$

p is a pixel $\in A$,

$|A|$ is the size of A,

$C(p)$ is the 3 – D color vector

Result

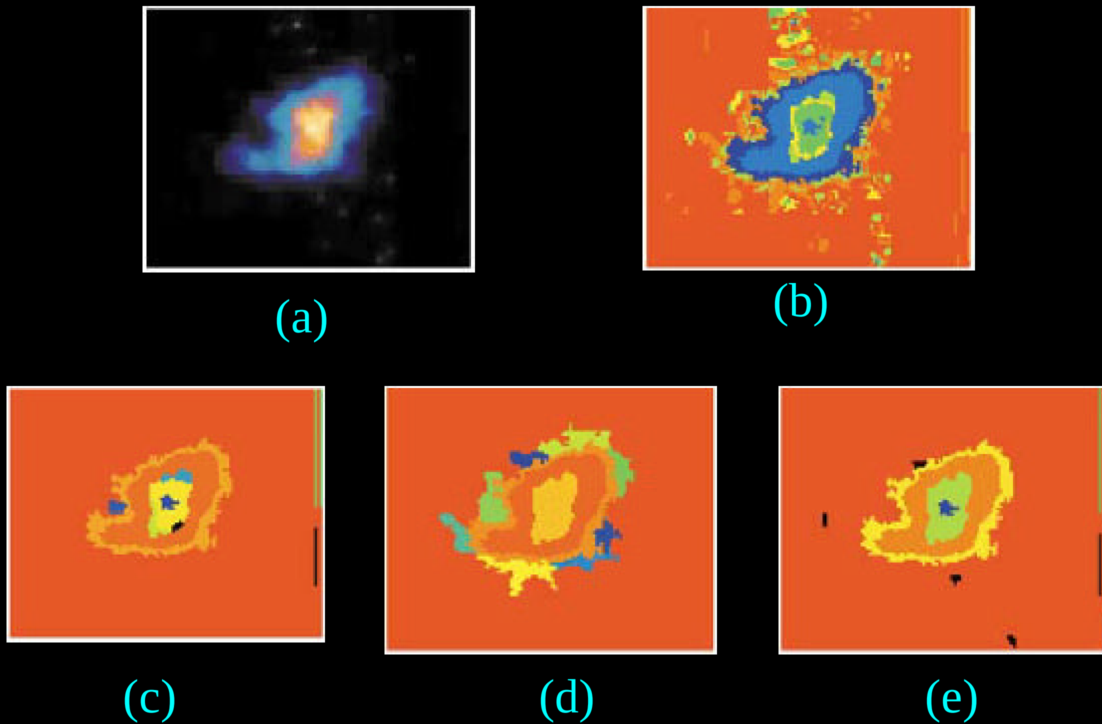


Fig. 3. Comparison of clustering results generated be three different spatial merging methods: (a) shows an egg nebula image, (b) shows the clusters generated by the fuzzy clustering algorithm with =16, (c), (d), and (e) show the clustering result generated by method 1, 2, and 3, respectively, from (b