Pattern Recognition Letters 30 (2009) 1496–1506

Contents lists available at ScienceDirect

Pattern Recognition Letters

journal homepage: www.elsevier.com/locate/patrec

Learning a color distance metric for region-based image segmentation

Antonio C. Sobieranski [a], Daniel D. Abdala [b], Eros Comunello [c], Aldo von Wangenheim [a,*]

[a] Image Proc. and Computer Graphics Lab – LAPIX, Federal UFSC – University of Santa Catarina, Brazil
[b] CS Department, University of Münster, Münster, Germany
[c] Graduate Program in Applied Computer Science, CS Department, Universidade do Vale do Itajaí – Univali, São José, Brazil

ARTICLE INFO

Article history:
Received 8 April 2008
Received in revised form 28 May 2009
Available online 7 August 2009

Communicated by Y.J. Zhang

Keywords:
Region-based color image segmentation
Mumford–Shah algorithm
Distance metric learning
Mahalanobis distance
Global optimization

ABSTRACT

In this paper we describe an experiment where we studied empirically the application of a learned distance metric to be used as discrimination function for an established color image segmentation algorithm. For this purpose we chose the Mumford–Shah energy functional and the Mahalanobis distance metric. The objective was to test our approach in an objective and quantifiable way on this specific algorithm employing this particular distance model, without making generalization claims. The empirical validation of the results was performed in two experiments: one applying the resulting segmentation method on a subset of the Berkeley Image Database, an exemplar image set possessing ground-truths and validating the results against the ground-truths using two well-known inter-cluster validation methods, namely, the Rand and BGM indexes, and another experiment using images of the same context divided into training and testing set, where the distance metric is learned from the training set and then applied to segment all the images. The obtained results suggest that the use of the specified learned distance metric provides better and more robust segmentations, even if no other modification of the segmentation algorithm is performed.

1. Introduction

Color similarity computation in region-based segmentation algorithms is usually based on an Euclidean norm calculated from the color vectors, where all channels are regular and equally weighted. If the variances among the dimensions are equal, simple discriminating functions such as Euclidean distance can be employed. However, if an object is composed by information dispersed in the color space, such as the starfish shown in Fig. 1, the scale space parameter needs to be higher to allow the merging of the entire object, in order to avoid segment leakages. Other color spaces could be used to improve the quality of similarity (e.g. HSI or YPbPr), but these are also linear and the segmentation in some cases will still require some kind of post-processing. Examples of post-processing algorithms presenting interesting results are (von Wangenheim et al., 2007; Dupuis and Vasseur, 2006; Kato and Pong, 2006; Deng and Manjunath, 2001). One possible way to avoid a post-processing step could be to employ an improved similarity function, even when using an established color image segmentation algorithm.

The usage of distance metrics or improved similarity functions is addressed in many image processing works. In (Michailovich et al., 2007) an active contours method applied the Bhattacharya distance to drive the gradient flow. Renner (2003) states that a color space is inherently non-linear and uses Riemannian geometry and harmonic maps to develop an anisotropic diffusion filter. Shah (1991) studied earlier the usage of anisotropic diffusion aiming image segmentation. Protiere and Sapiro (2007) developed a semi-automated image segmentation method using Gabor Filters that, through manually selected image features, computes adaptive weights to drive a supervised segmentation. These features compose a connected network that defines the segmentation regions, and the number of objects is then defined by manually selected seeds. In (Xiang et al., in press) a pair-wise constraints approach in which a Mahalanobis distance metric is learned for data clustering is presented. In this work an example of interactive image segmentation is shown in which the classes are manually selected by the user. The information is then used as the featured space, where the RGB values of the seed points and the coordinates over the image compute a *5-dimensional* space in the form of (r, g, b, x, y). A general methodology for the application of a region-based segmentation method for color images, in which a learned distance metric is used to drive the merging of regions, however, has still not been established.

In this paper we describe an experiment where we studied empirically the application of a global optimum, image-specific

* Corresponding author. Tel.: +55 48 3331 9516; fax: +55 48 3331 9516-r16.
E-mail addresses: asobieranski@cyclops.ufsc.br (A.C. Sobieranski), abdalad@uni-muenster.de (D.D. Abdala), eros.com@univali.br (E. Comunello), awangenh@inf.ufsc.br (A.von Wangenheim).

0167-8655/$ - see front matter
doi:10.1016/j.patrec.2009.08.002

learned distance metric to be used directly as the discrimination function of a traditional region-based color image segmentation algorithm. The distance metric is inductively learned by the selection of seed points over the image, and differently of the pairwise constraints approaches, only the class of interest or a dissimilarity feature is need as the input data in the form of (r,g,b) values. In this approach, the coordinates (x,y) of input data in the image is not taken into consideration, and then its not used to drive the segmentation process. The idea is learning a distance metric based on the input data values in the color space domain, which is then used as a discrimination function in a region-based segmentation algorithm. To perform this experiment we chose a well-known region-based segmentation algorithm and an also well-known distance metric. The objective was to first test the approach

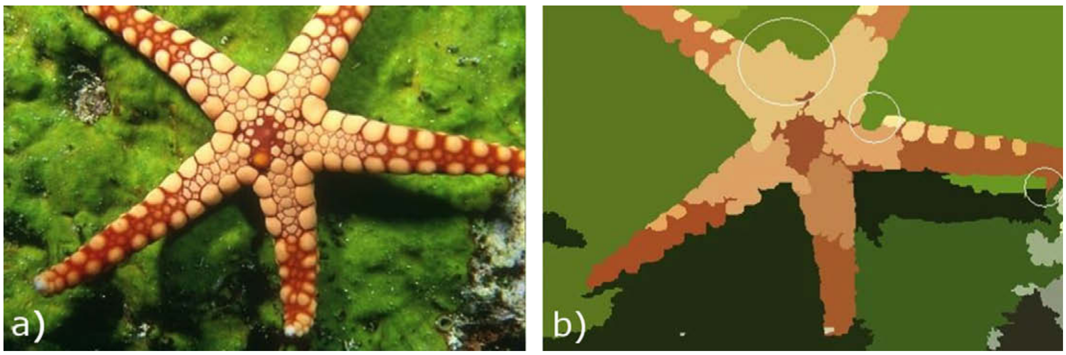

Fig. 1. (a) Original image. (b) Segmentation result produced with Mumford–Shah algorithm using $\lambda = 16384$ and a linear color distance in the RGB color space. The circles show inaccurate regions where starfish regions leaked into the background before the entire starfish segments were merged into one region.

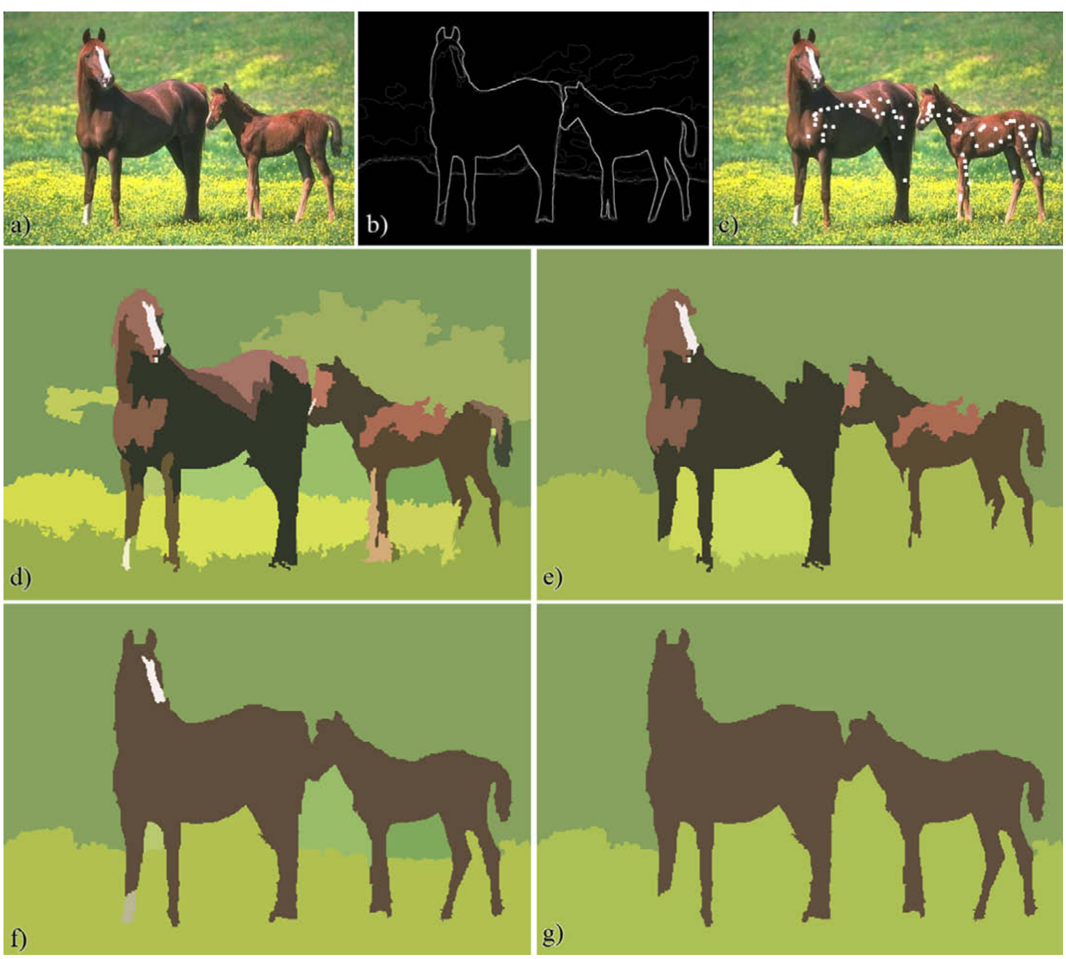

Fig. 2. (a) Original image #113016. (b) Ground truth-based border image. (c) Seeded image. (d), (e) Segmentation results using the RGB as color space presenting their best rand index and best BGM, respectively. (f) and (g) Segmentation results using the adaptive discrimination function generated by the *seed points* in (c) presenting, respectively, the results with best rand index and best BGM index.