Colour Image Segmentation Technique for Screen Printing

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ABSTRACT

Screen-printing is an industry with a large number of applications ranging from printing mobile phone logos to printing artworks on fabrics. In screen-printing, image segmentation plays a critical role in deciding both the cost and the quality attributes of printing. The work presented in this paper focuses on the development of an approach to colour image segmentation using a combined approach of *k*-means clustering and principal component analysis. The uncorrelated image data obtained through a principal component analysis was clustered using a *k*-means clustering algorithm. Since the study focused on the screen printing industry, the selection of the number of clusters *k* which is the most critical element is allowed to be set manually so that users can limit the number of colours to be segmented. It is shown that this approach produces a significant improvement in colour image segmentation. Results are also compared with another popular clustering algorithm called the mean-shift, which is normally used in feature space clustering.

1. INTRODUCTION

The introduction to screen printing given in Wikipedia is as follows [1]. "Screen printing is a printing technique that uses a woven mesh to support an ink blocking stencil. The attached stencil forms open areas of mesh that transfer ink or other printable materials which can be pressed through the mesh as a sharp-edged image onto a substrate. A roller or squeegee is moved across the screen stencil, forcing or pumping ink past the threads of the woven mesh in the open areas. Screen printing is also a stencil method of print making in which a design is imposed on a screen of silk or other fine mesh, with blank areas coated with an impermeable substance, and ink is forced through the mesh onto the printing surface".

From the very beginning, screen-printing is associated with fabrics. Today even modern mobile phone's logos are printed using screen printing methodologies.

The image segmentation plays a crucial role in screen-printing. Currently in the local industry, where this research was focused, the colour separation is done manually. Trained graphic artists manually draw the artwork to get separate layers of different colours. Some use software packages such as Adobe Illustrator and Adobe Photoshop to help this work. Some use sample manual drawings constructed by the graphic artists on an artwork to segment the artwork according to its respective colours. Each of the segmented films contains different colour segments of the original artwork. However, manual methods are time consuming and require skilled human resources. The research work discussed in this paper focused on producing segmented images from original artwork with very little manual effort.

Although segmentation of monochrome images has been a topic of interest in the past three decades, colour image segmentation has gained attention recently. This may be due to low computational power available during early days. There are many methods in monochrome image segmentation. These methods are based on either discontinuity or homogeneity of gray level values in a region. The approach based on discontinuity tends to partition an image by detecting isolated points, lines and edges according to abrupt changes in gray levels. The approaches based on homogeneity include thresholding, clustering, region growing, region splitting and merging. However, each of these segmentation techniques has their own advantages and disadvantages.

Artworks generally consist of many open curves and unbounded areas. Main objective in this research work is to segment the artwork with respective to colour based regions. The study of colour image segmentation strongly depends on its application area. Considering the local requirements, more focus was given to the feature space clustering approaches. One such clustering method used heavily in image segmentation is the *k*-means clustering method. There were numerous researches that have been conducted using *k*-means clustering for image segmentation in various applications.

Leydier et. al. [2] reported an adaptive segmentation system that was designed for colour document image analysis. The method is based on the serialization of a *k*-means algorithm that is applied sequentially by using a sliding window over the image. During the window's displacement, the algorithm reuses information from the clusters computed in the previous window and automatically adjusts them in order to adapt the classifier to any new local variation of the colours.

Ilea et. al [3] reported an implementation of a new adaptive technique for colour-texture segmentation that is a generalization of the standard *k*-means algorithm. The standard *k*-means algorithm produces accurate segmentation results only when it was applied to images defined by homogenous regions with respect to texture and colour since no local constraints are applied to impose spatial continuity. In addition, the initialization of the k-means algorithm is problematic and usually the initial cluster centers are randomly picked. These authors have presented an implementation of a novel technique to select the dominant colours from the input image using the information from the colour histograms. The main contribution of this work is the generalization of the *k*-means algorithm that includes the primary features that describe the colour smoothness and texture complexity in the process of pixel assignment. This paper also reports comparison between mean-shift clustering based segmentation method and modified *k*-means segmentation method.

Comaniciu et. al. [4] reported a general technique for the recovery of significant image features. This technique is based on the mean-shift algorithm, a simple nonparametric procedure for estimating density gradients. The advantage of this technique is that the elimination of some of the drawbacks in current methods (including robust clustering). With this technique, feature space of any nature can be processed.

2. METHODOLOGY AND IMPLEMNTATION

Since many methods are available for colour image segmentation, in this study several of popular techniques were implemented initially to identify the best method to be adopted for further developed for colour separation in screen printing. In this section, several methodologies are documented.

2.1 Image segmentations using thresholding

As for the basic level, segmenting an image using colour can be achieved using histogram thresholding.

- **Thresholding using grayscale**

In this technique, the colour image is first converted to a gray scale image. Then by studying the pixels vs. corresponding intensity values suitable thresholding values can be defined.

- **Thresholding using RGB**

The only difference in this method was applying multilevel thresholding to all three colour channels; Red, Green and Blue separately and then combine them. This preserves the colour information of the image unlike grayscale thresholding. In HSV colour space, hue (H) value is responsible for different colours of the image irrespective of the intensities and brightness. Thus, it is possible to use the same method discussed above with gray scale thresholding to segment colour images according to their colours. The Advantage in this method is that we can preserve the colour information of the image without handling all three components as in the RGB based method. The problem with this method is when image consists of low saturation and higher intensities hue component of the image is undefined.

2.2 Image segmentation in RGB vector space

This method uses Euclidean distance as colour similarity measure. This is done by using distances and thresholds to select whether a given colour is similar to other colour pixels in the image. This method was implemented following the method described by Gonzalez et. al. [5].

2.3 Segmentation using feature space clustering

Segmentation technique can be broken in to two steps (1) Categorize the points in the feature space into clustering (2) Map the clusters back to the spatial domain to form separate regions. These regions are the segmented parts in the image. Clustering was accomplished via the two methods discussed below.

- **Segmentation using *k*-means clustering via PCA**

The *k*-means clustering treats each object having a location in space. It finds a partition such that, objects within each cluster are as close to each other as possible, and as far from objects in other clusters as possible. *K*-means clustering requires the number of clusters to be partitioned and a distance metric to quantify how close two objects are to each other. In this study colour intensity values related to three different channels are considered as a location in feature space and the CIELab colour space was used as three colour channels. As an additional feature, the principal component analysis (PCA) [6] was used to uncorrelate the input data. The three colour channels are the data values which needs to be uncorrelated using PCA before using them in *k*-means clustering. PCA reduces correlation among colour space values. Later in the development phase YCbCr colour space was also used. Detail comparison of improvements in using different colour spaces is discussed later.

- **Segmentation using mean-shift clustering**

Most robust approach to cluster feature space is to use mean-shift algorithm. Unlike in *k*-means this clustering algorithm requires minimum human intervention. It does not need the number of clusters to be specified manually. Clustering algorithm itself decides the correct no of clusters to be separated. Nevertheless, users have to manually set the search widow size, where this algorithm is converged. The window size has very direct connection towards the decision of number of clusters. If the search window size happens to be too small, over segmentation might occur. On the other hand if it happens to be too large under segmentation might occur [4].

3. RESULTS AND DISCUSSION

3.1 Segmentation by thresholding

This method can successfully segment colour regions of images when they contain solid colours. Solid colour means colour regions that do not contain any gradients or shades. This method can be used only with human involvement since segmentation depending on the thresholding value manually selected by the user. The resultant segmentation achieved by this method is shown in Figure 1.

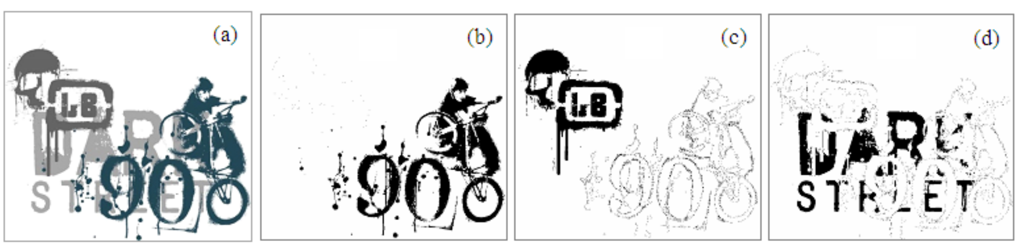

Figure 1: Resultant images of grayscale based segmentation

In Figure 1, image labeled (a) is the original artwork. Images labeled (b), (c) and (d) are the colour segmented images. Careful inspection shows that images labeled (c) and (d) have unwanted pixels which belong to different colours. This is due to the less precise threshold values selected by the user. However, it is hard for the user to select threshold value with 100% accuracy since the decision is based on visual inspection. It should be noted that although image labeled (b), (c) and (d) shown as binary images, they can be remapped into colour segments using the original image.

3.2 Segmentation by multiple thresholding (RGB)

In this method, thresholding is applied to all three-colour channels available in the image after inspecting its colour regions. This inspection allows user to select thresholding values relates to each of the colour channels and perform segmentation. Figure 2 shows the results of this segmentation process.

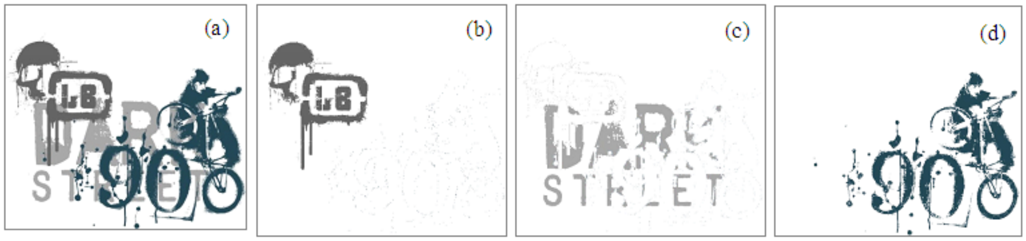

Figure 2: Resultant images of RGB based segmentation

In Figure 2, image labeled (a) is the original artwork. Images labeled (b), (c) and (d) are the colour segmented images. Although this method produced colour information contained in the image, the implementation had many drawbacks.

- Users need to manually inspect and select thresholding values for each of the colour regions which they need to segment. This is a tedious task to perform.
- When user manually sets the thresholding, it is not possible to set the thresholding values accurately for all three-colour channels. This leads to incorrect formation of colours when the image is reconstructed. This happens because all three-colour channels have to fused together to produce the final colour image.

3.3 Segmentation by RGB vector space

The RGB vector space method relies on thresholding value of distances. Here user has to decide on the thresholding value, although some heuristic thresholding value can be calculated using statistical methods.

Figure 3: Resultant image of RGB vector based segmentation

Commercial product such as Adobe Photoshop has a tool called ‘ColourRange’, which gives this functionality.

3.4 Segmentation by *k*-means clustering with and without PCA

In order to show the effect of the principal component analysis on this approach when it was used to uncorrelated colour intensity values in the image, comparison of both situations where without and with PCA are shown in Figure 4.

Figure 4: With and without PCA on image data

As shown in Figure 4, image labelled (a) denotes the original image, which is to be segmented. Images labelled (b), (c) and (d) are the outcomes when the PCA was not used in the segmentation. Images labelled (e), (f) and (g) are the outcomes when PCA was employed in the segmentation. When comparing images labelled (b) and (e), an improved segmented outcome can be seen in PCA applied segmentation process. When PCA was not applied segmented result was incorrect as seen in image labelled (b) where pixels from different colours are included in segmented result.

3.5 Segmentation by *k*-means using different colour spaces

Colour intensity values in the pixels forms the features, which is used in the *k*-means clustering algorithm. Therefore, selection of colour space to represent an image has a significant effect on segmentation mechanism when it is dealing with clustering.

Figure 5 show the segmentation output of the proposed system when different colour spaces were used to represent feature space. Colour spaces compared here are, RGB and CIELab.

When comparing image labeled (c) and (d) from RGB colour space and (i) and (j) from CIE colour space, It can be seen clearly that CIELab colour space gives better results other than RGB space (in RGB approach final segmented results has unwanted pixels). Results also show that best segmentation can be achieved with either CIELab or YCbCr colour spaces compared to RGB or HSV colour spaces.

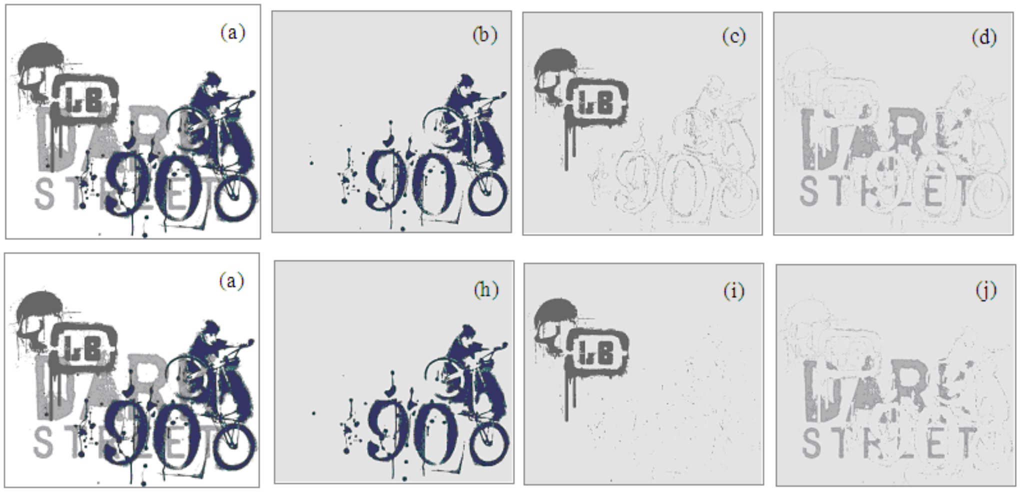

Figure 5: Colour Space Comparison (RGB and CIELab)

3.6 Comparison of segmentation by *k*-means and mean-shift

Figure 6 show the resultant segmentation outcome (5 most significant frames) by using *k*-means as clustering algorithm and setting number of colours to be *k*=6.

Figure 6: *K*-means based algorithm segmentation results

Figure 7 show the resultant segmentation outcome (5 most significant frames) by using mean-shift as clustering algorithm with Bandwidth = 1.

Both algorithms show very similar segmented outcomes. In both these cases, CIELab colour space was used in representing image colour values. Close inspections show that *k*-means clustering algorithm performs slightly better than mean-shift algorithm in correctly classifying colours.

Figure 7: Mean-shift based algorithm segmentation results

4. CONCLUSIONS

The main objective of this study was to develop a colour image segmentation technique to be used in screen-printing process. Although mean-shift algorithm allows the convenience by automatically detecting correct no of clusters in feature space, its classification accuracy is low in contrast to PCA and *k*-means clustering based segmentation approach. The main drawback is the limited control over segmentation selection. In addition, if the random initial seed point is incorrectly chosen, random selection of initial cluster centers in *k*-means clustering cause the whole system to fail. The feature space clustering based method seems to work well on many sample artworks and it can be successfully employed in screen printing industry.

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