

FAST COLOUR IMAGE SEGMENTATION USING A PRE-CLUSTERED CHROMATICITY-PLANE

Christian Scheering and Alois Knoll

University of Bielefeld
Postfach 10 01 31, 33501 Bielefeld, Germany
e-mail: {pcscheer, knoll}@TechFak.Uni-Bielefeld.DE

ABSTRACT

We present an efficient method for segmenting colour-images, which may be utilised in several robotic vision tasks. It categorises pixels according to their perceptual colour by exploiting the chromaticity contained in the signal of a standard colour camera as an index into a pre-clustered chromaticity plane. A technique called *perceptual colour grouping* is introduced to prevent oversegmentation. Experimental data demonstrate the performance of the proposed approach; computation time is reduced by a factor of 8.30 over previously known methods.

1. INTRODUCTION

There exist mainly three types of segmentation methods. The first is *region growing*, which was originally established as a segmentation technique for greylevel images [1] but still finds some attraction [2]. The second approach is *region splitting* or *histogramming* [3], by which an image is broken iteratively into homogeneous pieces. The most frequently used method [4], [5], [6] is *clustering*. The aim of the work presented here is the reduction of computation time for segmentation by utilising the HSV (Hue, Saturation, Value) perceptual colour space to calculate *in advance* a pre-clustered chromaticity plane for colour image segmentation.

2. PIXEL CATEGORISATION

The objective of pixel categorisation is to assign each of the pixels in an image to a specific categorical colour. Image regions may then be computed from the resulting one dimensional image using algorithms similar to those for grey level images (such as simple thresholding). Our method consists of two steps: First, the pre-clustered chromaticity plane is calculated. In the second step, this plane is used as a look-up table for categorising each pixel.

2.1. Pre-Clustering

Typically, colour images are the digitised result of a multi-dimensional sensor-measurement and every pixel is represented by a vector which is a member of a *colour space*. The vectors form *clusters* in this colour space if they belong to what the human eye perceives as a “constant colour” (see [7]). There exist several colour spaces in which the colour information is separable from the intensity information (e.g. YUV or HSV). The key idea of pre-clustering is the following: if, in a given colour space, it can be determined *in advance* for every pixel of a certain colour which category the pixel belongs to, then this mapping can be stored and reused.

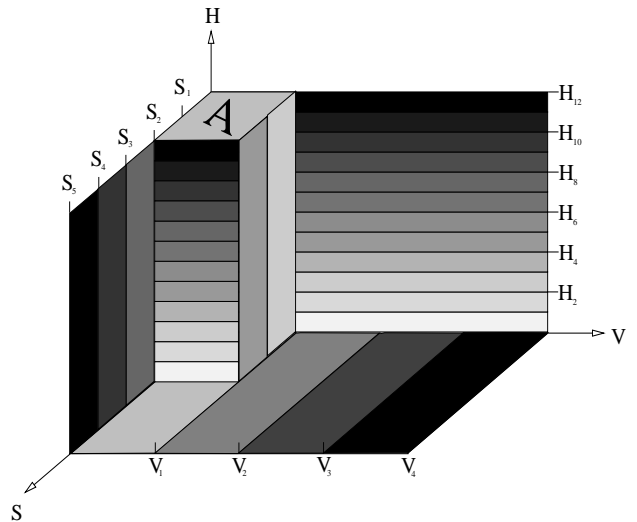


Figure 1: HSV quantisation with 12 hues, 5 saturations and 4 values and an achromatic region A

A two-dimensional pre-clustered chromaticity plane is computed by

- quantising the HSV into *categories*

- mapping categories to UV prototype-values
- assigning each UV value its category according to its nearest-neighbour prototype

The HSV-space is quantised into equally spaced intervals along each axis: 12 hues, 5 saturations and 4 values as shown in Figure 1. Using 12 hues makes it possible to include all the primaries red, yellow, green, cyan, blue and magenta with two sub-divisions. The latter, in turn, are quantised into $5 \times 4 = 20$ graduations. The total amount of $12 \times 20 = 240$ different HSV instances are the *categories* into which a pixel can fall. Each HSV category is represented by the first value inside the appropriate HSV interval.

To exploit only the colour-information contained in the digitised video-signal, a mapping from HSV categories to UV values is established. This is done via a transformation from HSV to RGB (see [8]) followed by a mapping from RGB to YUV (see [9]). For every HSV category, its corresponding UV value is calculated, which is considered as a prototype instance for the category in the UV chromaticity plane. These prototypes are then used to assign *every* point in the UV plane its nearest-neighbour category using the euclidean norm as distance function. The result is the *pre-clustered chromaticity plane*.

2.2. Perceptual Colour Grouping

Using 240 different pre-calculated clusters breaks *perceptually* homogeneous colours into separate regions. Several authors [4], [10] proposed different types of post-processing in order to re-merge those regions again, mainly kinds of *region growing* using special distance functions. A simple approach is used in our work. Due to the fact that HSV is close to human perception [7], the 12 different hues are used to group the 240 clusters into *perceptual colour groups*. Technically, this is achieved by introducing only 12 clusters for the former 240 different colour categories and generating a new pre-clustered UV-plane.

2.3. Achromatic Region

Before generating the full pre-clustered plane, an extra *achromatic category* [11] is introduced in order to deal with low saturated values. We have chosen those HSV-instances to be achromatic which are located below the first V-bin and below the second S-bin (the A-Part in Figure 1). The UV-values calculated for those HSV-categories form an *achromatic region* including the *real* achromatic point in the UV plane where no colour-information is available ($(u, v) = (0, 0)$). If, during the segmentation step, a pixel's category is *achro-*

matic, then it will be categorised in one of 8 additional greylevel categories. Using the UV chromaticity plane requires only $2^{16} = 65536$ Bytes (8 Bits per Channel). This means that using *full* chromaticity needs only 64 KBytes of storage compared to a full RGB “chromaticity cube” with $2^{24} = 16$ MBytes. Moreover, generating the pre-clustered plane does not need *a priori* knowledge about the scene (i.e. kind of objects, illumination, number of objects etc.).

3. EXPERIMENTAL RESULTS

Figure 2 shows a scene consisting of 3 egg-cups and an egg on a white table. The cup containing the egg is blue; the leftmost is blue-green and the rightmost is yellow. The egg itself is light brown. A YUV image of the scene was recorded with a standard one chip CCD colour camera and segmented with the proposed algorithm using full 240 colour-categories. Figure 3 shows the detected regions. Due to the curved nature of

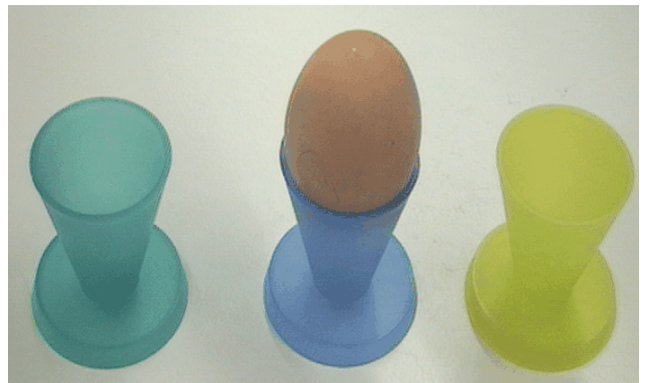


Figure 2: Scene of three egg-cups and an egg

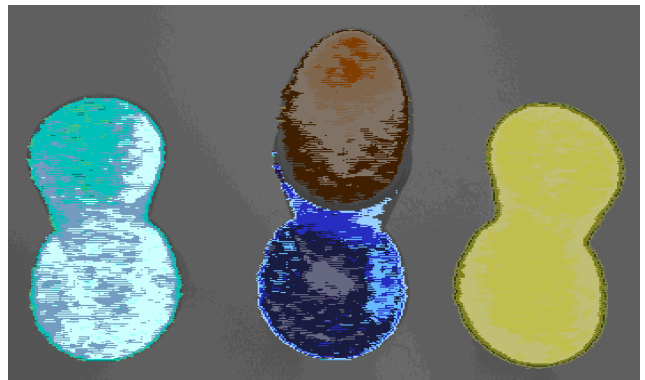


Figure 3: Segmented image with 240 colour-categories

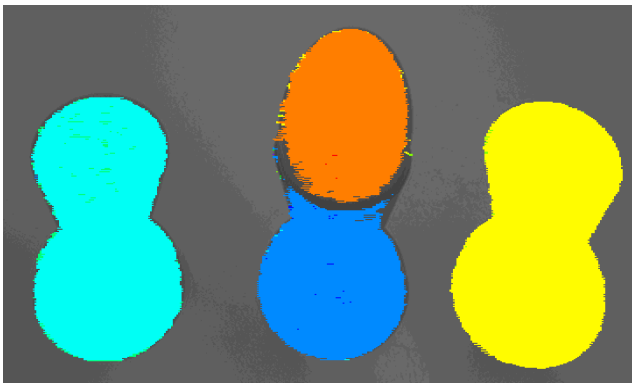


Figure 4: Segmented image using perceptual groups

the displayed objects, an oversegmentation occurred. It may be avoided by using only *perceptual colour groups*. With this simple method each egg-cup and the egg itself are now detected almost as a single region as shown in Figure 4.

| Approach | Machine | Image-Size | Time/s |
|------------|----------|------------------|--------|
| Our Method | Sun5/70 | 512×512 | 0.15 |
| [5] | Sun4/200 | 512×512 | 2.00 |
| [2] | Sun10 | – | 7.00 |

Table 1: Time used for segmentation

Due to the simple run-time step, the time required to categorise an image is very short when compared to other approaches. In [5] the time to cluster a 512×512 greylevel image is reported to take approximately 2s on a Sun4/200, but no times are reported for colour-images. In [2] a time of 7s on a SPARC 10 is needed to detect selected colours. The times needed for our approach are shown in Table 1.

4. CONCLUSION

We described a new fast and efficient way for scene-independent colour segmentation using a pre-clustered chromaticity plane. No special purpose hardware is necessary and a standard composite-video-signal can be used *directly* without any colour space transformations. Complexity is dramatically reduced by using clusters in advance rather than searching for them in some kind of feature-space. A simple method called *perceptual colour grouping* is proposed in order to preserve perceptually homogeneous regions in a scene-image.

5. References

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