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*Jerzy Korzeniewski**

METHOD OF COLOUR SEGMENTATION IN TWO DIMENSIONAL IMAGES

Abstract. The paper is divided into two parts. In the first part an overview of some selected methods of segmenting colours in two dimensional images is given. In the second part a new algorithm is proposed. The new algorithm is different from other algorithms due to its stress on accuracy of colour classes, the smallest possible number of colour classes (conditionally on paramameter choice) and due to smaller stress on the small number of eventual segments. The algorithm performance is assessed through applications to the segmentation a couple of colourful images.

Key words: colour segmentation, EM algorithm, non-parametric density estimation, pixel clustering.

1. INTRODUCTION

Image segmentation is a basic task in such areas as image search in multimedia libraries, medical photos analysis, object recognition in industry, robot control and many others. Searching through the Web pages and through literature one can find a number of methods which were invented to deal with the problem: pixel based techniqnes (Pauwles, Frederix 1999), area based techniques (Skarbek, Koschan 1994), edge-detection (Gevers, Ghebreab, Smeulders 1998), physics-based segmentation (Klinker, Shafer, Kanada 1990), non-parametric colour density estimation, EM algorithm based on marginal colours distribution (Dempster, Laird, Rubin 1977). All of these methods have their own advantages and disadvantages or features, as one should call them more appropriately. The trouble with comparing these methods with one another lies in the problem of the choice of criterion. Most of the methods were developed with a view to meet different criteria. Those which give accurate colour segmentation are not fast enough and vice versa, those which give reasonable

* PhD, Department of Statistical Methods, University of Łódź.

(in most applications) number of colour segments do not define colours precisely enough and so on. Below some examples of applications of some methods mentioned above are given and intuitively and visually assessed.

In Fig. 1 there is an example of applying the algorithm based on non-parametric colour density estimation to the segmentatien of an artificially created image consisting of a circle and a background of "smooth" transition between quite different colours (e.g. blue and yellow). The main idea of the method is to estimate the density of colours (suitably defined) with the formula

$$f(g) = C\sum_i K_\sigma(g - g_i),$$

Where g_i denotes level of grey of pixel i, C is a certain constant, and the kernel used was a Gaussian

$$K_\sigma(g) = \frac{1}{\sqrt{2\pi\sigma}} \exp\left(-\frac{g^2}{2\sigma^2}\right).$$

When the colour density was estimated it was possible to "hill climb" in the list of knot points (the one seen in the middle picture) in order to find a local peak for each data point. That is why the result is composed of two segments because linking any pixel with its local colour peak is the feature of the algorithm, therefore pixels of quite different colours can be linked through gradual steps.

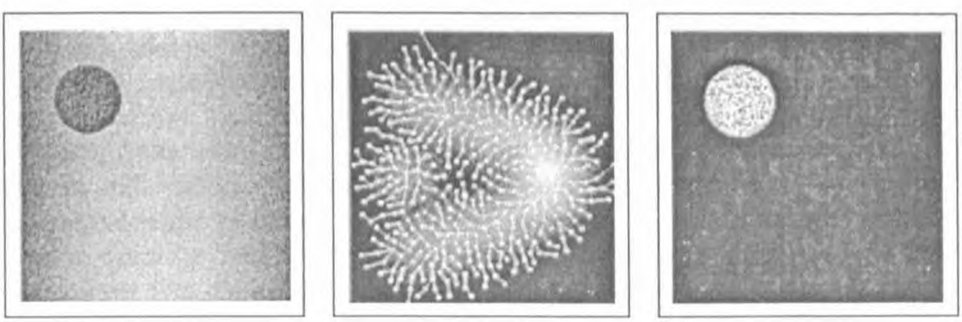

Fig. 1. An example of applying algorithm based on non-parametric density estimation to the segmentation of an image with smooth transition between colours

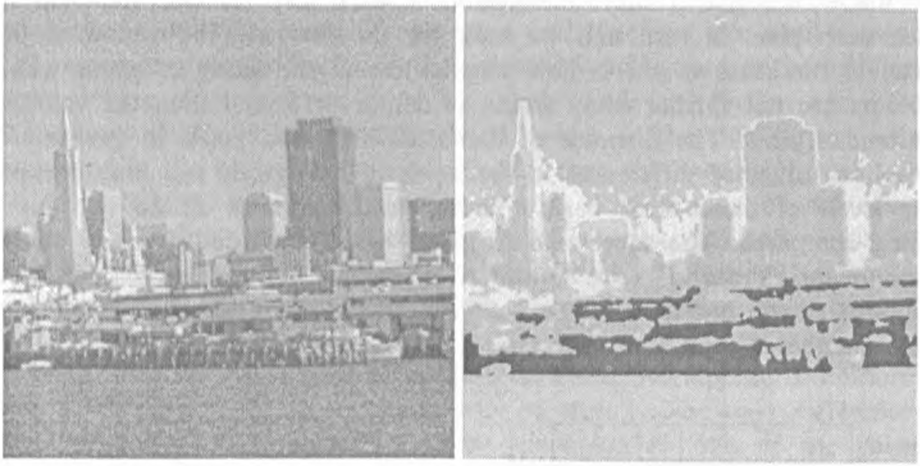

Fig. 2. An example of applying EM algorithm to the segmentation of a city's landscape

In Fig. 2 a typical example of applying EM algorithm to the segmentation of a city landscape (it was obtained at http://ciips.ee.williams.uwa.edu.an/$\sim$). The main idea of this algorithm is to present the density of the marginal distribution of the intensities of grey in the form of the sum of local densities which are supposed to be known through assumed prior densities. Then the coefficients of this presentation are estimated (E-step) and, next, the posterior probabilities for each pixel being of each colour are calculated and each pixel is assigned to its most likely colour (M-step). The segmentation of the black-and-white photo results in a couple of shades of greyness (six or seven) corresponding, more or less, to darker and brighter fragments of the image. More or less is a proper phrase because not all fragments are correctly assigned to colour.

2. NEW ALGORITHM PROPOSAL

A new algorithm we want to propose consists of a number of stages, each of which consists of a number of steps. The number of stages is not constant and depends on the precision of segmentation we want to achieve. The steps of each stage are the following:

1) establishing best neighbourhoods for each pixel,
2) linking neighbourhoods with similar colours,
3) separating a number of initial colours,
4) establishing best neighbourhoods for the colours separated,
5) removing from image pixels assigned to any of the colours separated.

Below, we give a short description of each step. In the first step we visit each pixel in turn and we look for the best neighbourhood of this pixel in the sense of the largest neighbourhood consisting of pixels whose colours are not further away from the colour of pixel i than the value of parameter *par1*. The distance of the colours of two pixels is the sum of absolute values of differences in the levels of red, green and blue between the levels of these three basic colours, in the colours of the two pixels being compared. The succession of pixels being compared depends on the type of neighbourhood we consider. Altogether, there are five different types as shown in Fig. 3. Type 3 is type 2 rotated 90 degrees around pixel with number 1, and type 5 is type 4 transformed in the same way.

type 1

		90	73	74	75	76	91		
	89	72	40	41	42	52	77	92	
	71	39	23	24	25	43	53	78	93
70	38	22	14	10	15	26	44	54	79
69	37	21	9	2	3	16	27	55	80
68	36	13	8	1	4	11	28	56	81
67	35	20	7	6	5	17	29	57	82
66	48	34	19	12	18	30	45	58	83
	65	47	33	32	31	46	59	84	94
	88	64	49	50	51	60	85	95	
		87	63	62	61	86	96		

type 2–3

	51	39	40	41	42	43	44	56	
52	38	24	14	15	16	17	25	45	53
37	23	13	6	1	2	7	18	26	46
36	22	12	5	4	3	8	19	27	47
35	34	21	11	10	9	20	28	48	54
	50	33	32	31	30	29	49	55	

type 4–5

					36	37	38
				35	19	20	39
			34	17	18	21	40
		33	16	8	12	22	41
	32	15	2	3	9	23	
31	14	7	1	4	24		
30	11	6	5	25			
29	13	10	26				
	28	27					

Fig. 3. Types of neighbourhoods used in pixel clustering

After assigning to each pixel the largest possible neighbourhood (with established colour i.e. levels of red, green and blue) we link similar colours i.e. we create groups of colours, the colour of each group is the arithmetic mean colour of the colours of all neighbourhoods not further away from the colour of the initial neighbourhood (which is the first largest neighbourhood in the list of all neighbourhoods) than the parameter *par2* value.

After linking colours of neighbourhoods into groups of colours we arrive at a certain number of colours (usually very large) and we perform step 3 by choosing first n colours in the list of all colours. Each of the colours chosen is further from all other colours chosen than twice the number $par1 + par2$.

Separation in step 3 is done in order to avoid overlapping of colours in step 4 which is made in a similar way as step 1. The only difference is that neighbourhoods consist of pixels belonging to one of the colours separated in step 3. In step 5 we remove (e.g. set colours of the pixels already assigned to be negative numbers) from the image pixels which have been assigned to any of the neighbourhoods established in step 4 and we can start next stage carried out in identical way. The number of stages needed to assign all pixels to some colours is usually big (a couple of dozen) for the same values of *par1* and *par2* throughout the algorithm. However, about 90% of all pixels can be assigned to colours in the first couple of stages (five or six).

The number of stages and the number of colours defined in each stage obviously depends the choice of parameters *par1* and *par2*. However, it turns out, that these values cannot be too small, because it results in too many similar colours, and they cannot be too big, because it results in generating new colours, not present in the original image (while defining new colours through arithmetic means). For a general sort of image one can use values $par1 = 8$ and $par2 = 5$. Segmentation is almost the same for parameters values smaller or greater by one.

3. ALGORITHM APPLICATION

To see hew the algorithm performs let us apply it to a general sort of image like e.g. a photograph of a building seen in Fig. 4. The results of each of six stages are shown in Fig. 5 and the colours received in each stage are given in Tab. 1. Each picture in Fig. 5 corresponds to one stage and contains only pixels assigned to colours in this and earlier stages. The segmentation was performed for parameters $par1 = 8$ and $par2 = 5$.

Fig. 4. A photograph of a castle to be segmented with the new algorithm

Fig. 5. Results of first six stages of segmentation of a castle's image with the new algorithm (first three in the upper row and last three in the bottom row)

Table 1

Colours defined in each of the six stages

Stage 1			Stage 2			Stage 3			Stage 4			Stage 5			Stage 6		
R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B
217	225	224	227	233	235	222	229	228	230	236	238	232	232	222	120	146	122
172	193	196	212	220	219	206	216	215	228	227	215	110	140	118	105	97	63
200	212	212	134	208	209	234	239	242	216	217	202	131	148	127	106	133	107
237	242	244	175	183	164	188	193	173	159	170	152	222	223	210	214	222	223
4	28	33	165	190	193	224	221	204	194	205	203	87	106	82	171	144	84
0	3	18	60	65	42	188	206	208	94	112	89	207	209	193	215	212	192
18	15	22	180	198	200	170	176	159	119	136	113	142	160	141	79	90	65
28	45	38	63	42	30	34	29	28	182	186	166	195	130	68	88	101	76
201	201	181	195	198	173	74	83	57	145	157	134	114	129	102	136	155	134
186	203	203	160	168	145	128	142	120	57	72	52	87	90	58	91	120	93
166	174	154	140	152	130	80	33	24	205	204	185	148	87	45	192	123	59
35	61	53				153	163	140	72	92	73	82	71	49	178	179	155
						98	118	96	77	49	36	165	171	147	198	209	207
						46	53	39	197	195	172	186	181	161	148	163	144
						16	39	42				97	47	25	174	196	200
															192	191	167

4. CONCLUSIONS

Many practical applications of the algorithm proposed allow us to assess it in the following way.

1. The algorithm is different from other algorithms with respect to putting more stress on accurate segmentation of colours and less stress on the small number of segments;

2. The algorithm is practically unsupervised because one can always use values of parameters *par1* = 8 and *par2* = 5 unless one needs very fine differentiation between colours and is not bothered with thousands of segments which result; in such situations one should use smaller parameters;

3. The colours defined by the algorithm are well defined i.e. there are no very similar two colours;

4. The algorithm is relatively slow, each stage takes about 10 minutes on a 900 MHz computer, but 90% of this time is wasted for reading and writing data on disc; therefore the whole time could be much smaller if software with bigger operating memory were used.

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Jerzy Korzeniewski

METODY SEGMENTACJI KOLORÓW W OBRAZACH DWUWYMIAROWYCH

Artykuł składa się z dwóch części. Pierwsza zawiera przegląd wybranych metod segmentacji kolorów w obrazach dwuwymiarowych. W drugiej części zaproponowany jest nowy algorytm segmentacji kolorów. Nowy algorytm różni się od innych tym, że kładzie nacisk na dokładne zdefiniowanie klas kolorów oraz na jak najmniejszą ich liczbę (warunkowo względem ustalonych wartości parametrów), natomiast mniejszy nacisk jest położony na otrzymanie małej liczby segmentów. Działanie algorytmu jest ocenione poprzez porównanie segmentacji typowego obrazu dwuwymiarowego z segmentacjami wykonanymi przez inne algorytmy.