IMAGE CLASSIFICATION ACCORDING TO THE DOMINANT COLOUR

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Abstract: The aim of this work is to develop a user-friendly software allowing him to classify images according to their dominant colour expressed through linguistic expressions. With this aim in view, images are processed and stored in a database. The processing consists in assigning a profile to each image. To do this, we consider the pixels of the images in the colorimetric space HLS and then a restricted number of colours classes are built. These classes depend on the hue (H). For each colour class a certain number of subclasses depending on the lightness (L) and the Saturation (S) are defined. Finally the profile is drawn using the pixels membership of the classes and subclasses. Thus starting from a linguistic expression of a colour, the user can extract images from the database.

1 INTRODUCTION

The classification of images by colour is of the greatest importance in several fields and activities (Fouloy, 1990), (Le Saux, 2003), ... For example, Hammami and al. use colour histogrammes to determine whether an image contains a lot of skin texture or not in order to classify the images and to finally detect adult and sexual contents (Hammami et al., 2002).

In medical applications, the work we detail in this article can be used to propose a general methodology to classify medical images sets or sequences in order to help medical expert forecasts and analysis, like tumors detection, for example. In industrial applications such as cosmetics it can be interesting to work on skin colour to help the make-up manufacture. Another example lies in advertising where our process can help the business man to find more easily and quickly the image that corresponds to his selection criteria.

In the process we propose, profiles are assigned to images and depend on the quantity of pixels that belong to colour classes.

The paper is organized as follows: section 2 explains about our choices for colour spaces while section 3 is devoted to the problem of colour representation where fuzzy membership functions are used. In section 4 we focus on the profile determination for each new entry (image) in the database. Finally the software we have developed is presented in section 5 with screen captures and section 6 concludes this article.

2 COLOUR SPACES

One of the spaces usually used to represent the colour on a screen is the RGB space (Red, Green, Blue). It is a three dimensional space representing the three primary colours that usually vary from 0 to 255. The origin of this space (0,0,0) corresponds to the lack of colour which represents the ”black” colour. On the other hand the point (255,255,255) corresponds to the maximum of colour which represents the ”white”. The representation of the colours in this space gives us a cube (cf. figure 1).

However this space is not appropriate for our problem because three dimensions (R, B and G) are necessary to identify a colour. To facilitate the colour identification we choose a space that allows us to characterize a colour with only one dimension: its

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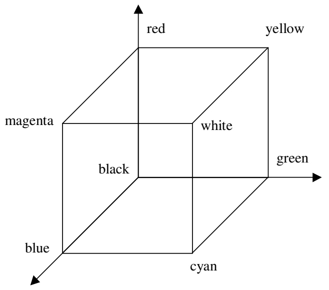

Figure 1: The RGB space

hue. Indeed hue is enough to recognize the colour, except when the colour is very pale or very somber. This space is called HLS (Hue, Lightness, Saturation) where saturation corresponds to the quantity of ”white” in the colour and lightness corresponds to the light intensity of the colour. This space can be represented through a cylinder or a bi-cone (cf. figure 2).

H is defined as an angle but we can also represent it in the interval [0,255] as the other components L and S. The difference between H and the other components is that its definition interval loops which means that 0 and 256 are the same points. The ”pure” red (represented in RGB space by the point (255,0,0)) corresponds to an angle equal to 0 for h, a saturation s equal to 255 and a lightness l equal to 128.

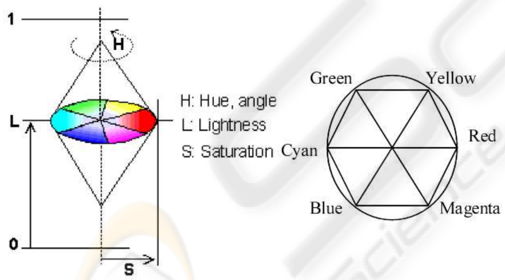

Figure 2: The HLS space

For this problem, we limit ourselves to the nine fundamental colours defined by the set $\mathcal{T}$ representing a good sample of colours (dimension H) :

$\mathcal{T}$ = {*red, orange, yellow, green, cyan, blue, purple, magenta, pink*}

This set corresponds to the seven colours of Newton (Roire, 2000) to which we have added colour pink and colour cyan. Of course, this choice is not restrictive, we can modify the set of colours as desired.

3 COLOUR REPRESENTATION

As we have seen HLS space is convenient for our problem but it is a non UCS (uniform colour scale) space (Truck, 2002), (Herrera and Martinez, 2001). Indeed our eyes don’t perceive small variations of hue when colour is green ($h = \pm 85$) or blue ($h = \pm 170$) while they perceive it very well with orange ($h = 21$) for example.

Thus to model the fact that the distribution of colours is not uniform on the circle of hues, Truck and al. propose to represent them with trapezoidal or triangular fuzzy subsets (Truck et al., 2001a).

For each colour of $\mathcal{T}$ they built a membership function varying from 0 to 1 (f_t with $t \in \mathcal{T}$). If this function is equal to 1, the corresponding colour is a ”true colour” (cf. figure 3).

These functions were built using colours definition (*www.poupre.com*). For each fundamental colour, the associated interval is defined according to linguistic names of colours. For example to construct f_{yellow}, we can use colour ”mustard” whose hue is equal to 55 and whose membership to f_{yellow} is equal to ± 0.5.

For some colours, the result gives a wide interval. It is the case for the colours ”green” and ”blue” which are represented by trapezoidal fuzzy subsets.

For the construction of these functions, in this article we suppose that two functions representing two successive colours have their intersection point value equal to 1/2. It means that when h corresponds to an intersection point it can be assigned to both colours with the same weight.

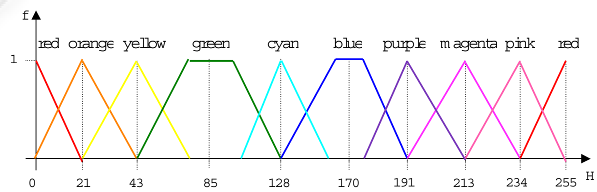

Figure 3: The dimension H

As usual (Bouchon-Meunier, 1995) we denote (a, b, α, β) a trapezoidal fuzzy subset (cf. figure 4). When the kernel is reduced to only one point, it is a triangular subset denoted by (a, α, β) since $a = b$.

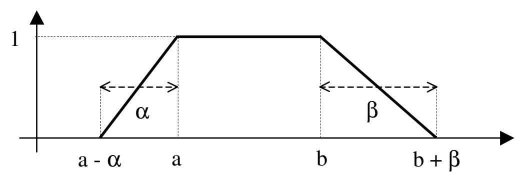

Figure 4: Trapezoidal fuzzy subset

Now we can define the membership function of any colour t :

$$\forall t \in \mathcal{T},\, f_t(h) = \begin{cases} 1 & if \quad h \geq a \\ & \wedge \quad h \leq b \\ 0 & if \quad h \leq a - \alpha \\ & \wedge \quad h \geq b + \beta \\ \frac{h-(a-\alpha)}{\alpha} & if \quad h > a - \alpha \\ & \wedge \quad h < a \\ \frac{(b+\beta)-h}{\beta} & if \quad h > b \\ & \wedge \quad h < b + \beta \end{cases}$$

For example, for $t = orange$ we have a triangular subset with $(a = 21, \alpha = 21, \beta = 22)$:

$$f_{orange}(h) = \begin{cases} 0 & if \quad h \geq 43 \\ \frac{h}{21} & if \quad h < 21 \\ \frac{43-h}{22} & if \quad h \geq 21 \end{cases}$$

For $t = green$ we have a trapezoidal subset with $(a = 75, \alpha = 22, b = 95, \beta = 33)$:

$$f_{green}(h) = \begin{cases} 1 & if \quad h \geq 75 \\ & \wedge \quad h \leq 95 \\ 0 & if \quad h \leq 43 \\ & \wedge \quad h \geq 128 \\ \frac{h-43}{22} & if \quad h > 43 \\ & \wedge \quad h < 75 \\ \frac{128-h}{33} & if \quad h > 95 \\ & \wedge \quad h < 128 \end{cases}$$

Moreover if we want to complete the modelisation, it is necessary to take into account the two other dimensions (L,S). A scale representing the colorimetric qualifiers is associated to each dimension. These two intervals are divided into three: the first subinterval corresponds to a low value, the second to an average value and the last to a strong value. This division gives for saturation S: ”dull”, ”moderately dull” and ”saturated”; and for lightness L: ”gloomy”, ”heavy” and ”pallid”.

These two scales are then aggregated to give nine qualifiers for colours defined by the following set (cf. figure 5) (Truck et al., 2001b):

$\mathcal{Q}$ = { *somber, dark, deep, gray, medium, bright, pale, light, luminous* }.

Each element of the set $\mathcal{Q}$ is associated to a membership function varying between 0 and 1 ($\tilde{f_q}$ with $q \in \mathcal{Q}$). For these functions the intersection point value is also supposed equal to 1/2 (cf. figure 7). Every function is represented through the set $(a, b, c, d, \alpha, \beta, \gamma, \delta)$ (cf. figure 6).

The membership function of any qualifier q is defined below :

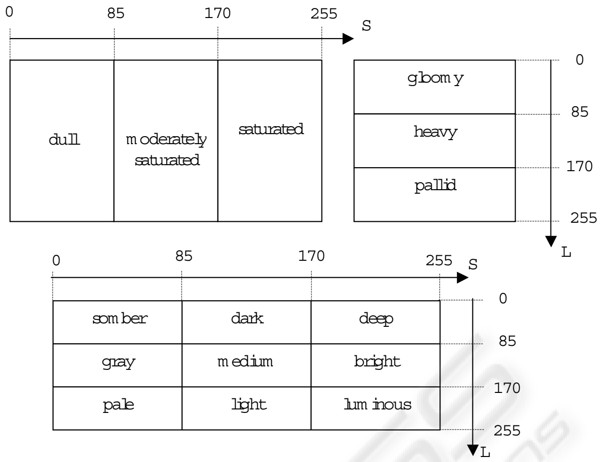

Figure 5: Fundamental colour qualifiers

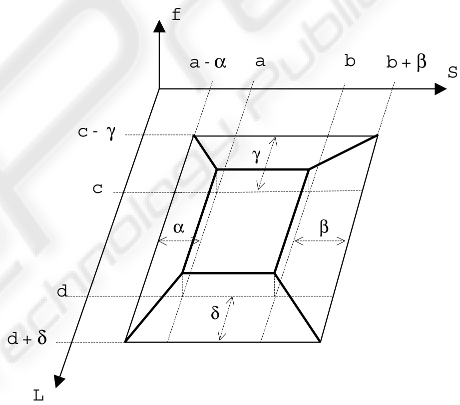

Figure 6: Trapezoidal 3-D fuzzy subset

$\forall q \in \mathcal{Q}$,

$$\tilde{f_q}(l, s) = \begin{cases} 1 & if \quad a \leq s \leq b \\ & \wedge \quad c \leq l \leq d \\ 0 & if \quad a - \alpha \geq s \geq b + \beta \\ & \vee \quad c - \gamma \geq l \geq d + \delta \\ \frac{l-(c-\gamma)}{\gamma} & if \quad c - \gamma < l < c \\ & \wedge \quad \alpha l - \gamma s \leq \alpha c - \gamma a \\ & \wedge \quad \beta l + \gamma s \leq \beta c + \gamma b \\ \frac{(d+\delta)-l}{\delta} & if \quad d < l < d + \delta \\ & \wedge \quad \beta l - \delta s > \beta d - \delta b \\ & \wedge \quad \alpha l + \delta s > \alpha d + \delta a \\ \frac{s-(a-\alpha)}{\alpha} & if \quad a - \alpha < s < a \\ & \wedge \quad \alpha l - \gamma s > \alpha c - \gamma a \\ & \wedge \quad \alpha l + \delta s \leq \alpha d + \delta a \\ \frac{(b+\beta)-s}{\beta} & if \quad b < s < b + \beta \\ & \wedge \quad \beta l + \gamma s > \beta c + \gamma b \\ & \wedge \quad \beta l - \delta s \leq \beta d - \delta b \end{cases}$$

For example, for $q = somber$ we have $(a = \alpha = 0, b = 43, \beta = 84, c = \gamma = 0, d = 43, \delta = 84)$:

$$\tilde{f}_{somber}(l,s) = \begin{cases} 1 & if \quad s \leq 43 \\ & \wedge \quad l \leq 43 \\ 0 & if \quad s \geq 127 \\ & \vee \quad l \geq 127 \\ \frac{127-l}{84} & if \quad 43 < l < 127 \\ & \wedge \quad l > s \\ \frac{127-s}{84} & if \quad 43 < s < 127 \\ & \wedge \quad l \leq s \end{cases}$$

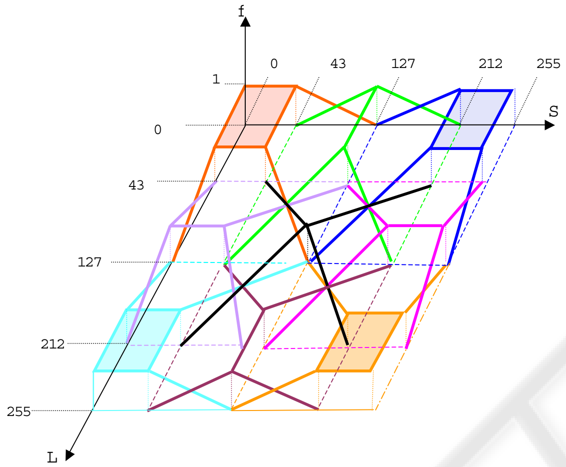

Figure 7: Dimensions L and S

4 IMAGE PROCESSING

The image processing aims at determining a profile corresponding to the various categories: the nine fundamental colours and the nine colour qualifiers (cf. figure 8). For each pixel of the image we can determine the values taken by the various membership functions of the categories. For each category the value obtained corresponds to the ratio between the sum, on all the pixels of the image, of the membership functions values and the number of pixels, which gives a quantity between 0 and 1. This quantity is the membership degree of an image to the given class.

The membership degree of an image to a certain class is defined as follow:

Let I be an image.
Let $\mathcal{P}$ be the set representing the pixels of I, except pixels more or less white or black.

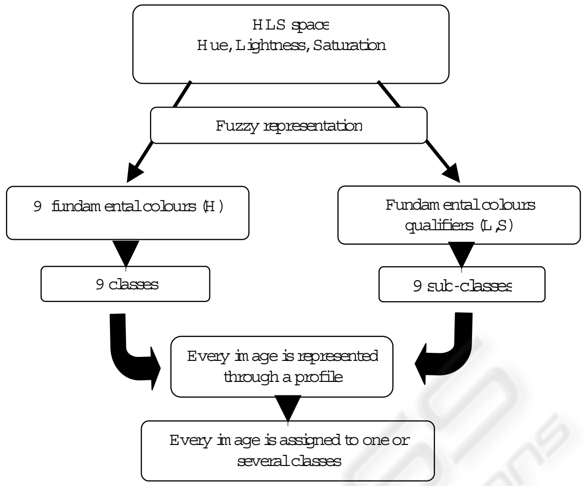

Figure 8: Image processing

Each element p of the set $\mathcal{P}$ is defined by its colour coordinates (h_p, l_p, s_p). p can be one pixel or a set of pixels. We can calculate the functions $f_t(h_p)$, $\tilde{f}_q(l_p, s_p)$ for $t \in \mathcal{T}$ and $q \in \mathcal{Q}$.

Let F_t and $\tilde{F}_{t,q}$ be the following functions, representing the membership degree of I to the classes t and (t, q):

- $F_t(I) = \dfrac{\sum_{p \in \mathcal{P}} f_t(h_p)}{|\mathcal{P}|} \; \forall t \in \mathcal{T}$
- $\tilde{F}_{t,q}(I) = \dfrac{\sum_{p \in \mathcal{P}} \tilde{f}_q(l_p, s_p) \times g_t(h_p)}{|\mathcal{P}|}$
  $\forall (t, q) \in \mathcal{T} \times \mathcal{Q}$
  with $g_t(h_p) = \begin{cases} 1 & if \;\; f_t(h_p) \neq 0 \\ 0 & else \end{cases}$

Example 1 *Let us consider only 2 pixels p_0 and p_1 to simplify.*

$$p_0 : \begin{cases} h_{p_0} = 178 \\ l_{p_0} = 50 \\ s_{p_0} = 100 \end{cases}, \; p_1 : \begin{cases} h_{p_1} = 173 \\ l_{p_1} = 255 \\ s_{p_1} = 128 \end{cases}$$

- $f_{blue}(h_{p_0}) = f_{blue}(178) = 0.9$
  $\tilde{f}_{somber}(l_{p_0}, s_{p_0}) = \tilde{f}_{somber}(50, 100) = 0.34$
- $f_{blue}(h_{p_1}) = 1$, $\tilde{f}_{somber}(l_{p_1}, s_{p_1}) = 0$

So, for class "blue" the value shall be:

$$F_{blue}(I) = \frac{f_{blue}(h_{p_0}) + f_{blue}(h_{p_1})}{2} = 0.95$$

And for class "somber" from "blue", the value shall be:

$$\frac{\tilde{f}_{somber}(l_{p_0}, s_{p_0}) \times 1 + \tilde{f}_{somber}(l_{p_1}, s_{p_1}) \times 1}{2}$$
$$\tilde{F}_{blue,somber}(I) = 0.17$$

Every image is defined by a profile of 90 elements ($|T| + |T \times Q| = 9 + 81$). A profile can be presented as follows :

$$[F_t(I), \widetilde{F}_{t,q}(I)]$$

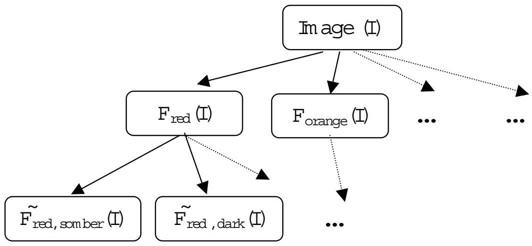

Figure 9: Profile representing an image

An image can be assigned to several classes, there are 90 classes, 9 principal : C_t with $t \in \mathcal{T}$, and 81 subclasses which correspond to a refinement of the research: $\widetilde{C}_{t,q}$ with $(t, q) \in \mathcal{T} \times \mathcal{Q}$.

As shown in figure 9 the classes can be represented through a tree with father-son relationship, the classes $C_t \, with \, t \in \mathcal{T}$ can be considered as fathers and the classes $\widetilde{C}_{t,q} \, with \, (t, q) \in \mathcal{T} \times \mathcal{Q}$ as their sons. For example the father class of class $\widetilde{C}_{red,somber}$ is C_{red}.

let us denote:

- $F^*(I) = \max_{t \in T}(F_t(I))$
- $\widetilde{F}^*_t(I) = \max_{q \in Q}(\widetilde{F}_{t,q}(I)) \; \forall t \in T$

An image I will be assigned to:

- The classes C_t if $F_t(I) \geq F^*(I) - \lambda$. with λ a tolerance threshold.
- The classes $\widetilde{C}_{t,q}$ if $F_t(I) \geq F^*(I) - \lambda$ and $\widetilde{F}_{t,q}(I) \geq \widetilde{F}^*_t(I) - \lambda$.

An image can be assigned to several classes, and it can be assigned to a subclass only if it is also assigned to its father class. For example, an image cannot be assigned to ”red, bright” class ($\widetilde{C}_{red,bright}$) if it is not assigned to the ”red” one (C_{red}).

5 PRESENTATION OF THE SOFTWARE

Information concerning the images are stored in a database (cf. figure 10). That helps us to optimise the exploitation of these information. Each image will be represented through its profile previously defined.

The software is divided into two sections, the first one corresponds to the treatment and the insertion of the images in the database, the second one to the exploitation of this database through requests with linguistic terms (cf. figure 11).

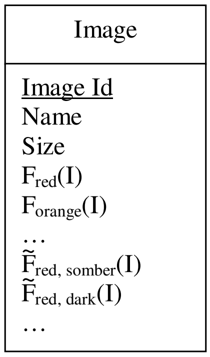

Figure 10: Database

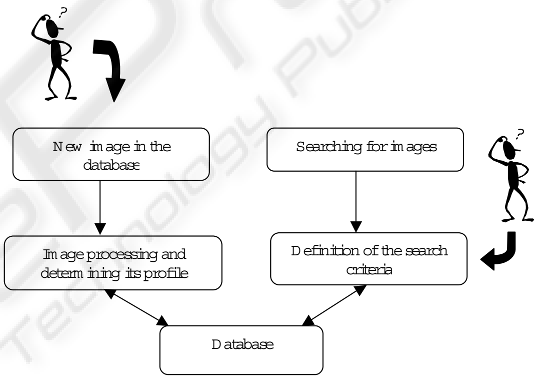

Figure 11: human-computer interaction

The image processing aims at building its profile. In the first section, a window allows us to select and display the image to be inserted in the database. Once the image is inserted the software displays all the stored images.

In the second section, the user of the software will have the possibility of carrying out research on two levels. The first one corresponds to the nine fundamental colours (dimension H), the second one to the nine colour qualifiers. For example, the images whose dominant colour is ”blue” for the first case and the images whose dominant colour is ”luminous blue” for the second (cf. figures 12 and 13).

Once the Hue is selected, the user has the possibility to refine his request by specifying a colour qualifier. For that, it is enough for him to choose one proposed in the list, or to click on the corresponding zone in the image.

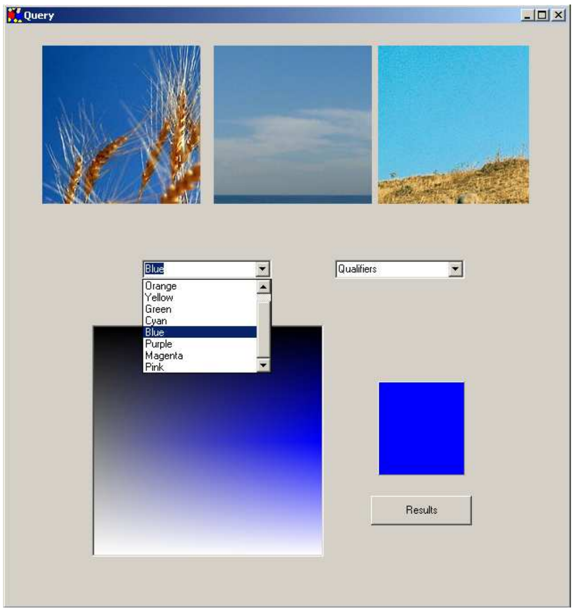

Figure 12: Query with only a color.

Figure 13: Query with a color *and* a qualifier.

6 CONCLUSION

We developed in this work an approach allowing us to classify images according to their dominant colour. We limited ourselves to fundamental colours and nine colour qualifiers; those can be widened without modifying the approach, we only have to make few modifications in the software. Moreover, as we have seen, black and white pixels have not been treated yet: the next perspective is to add two other classes for these special "colours".

For the image extracting from the database, it is not necessary to browse all the 90 classes defined in section 4. We can make a first selection through the nine fundamental colours and then look at the corresponding sons classes to refine the query.

In the database images are stored with their profiles, thus we can extend this approach to look for images which *don't* have a given colour or a set of colours.

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