# INTEGRATION OF LINGUISTIC KNOWLEDGE FOR COLOUR IMAGE SEGMENTATION

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## ABSTRACT

The Hue, Chroma, Intensity (HCI) space is well suited to colour images segmentation processing. In this paper, we used fuzzy logic for integrating specific knowledge of the Hue component. Based upon several linguistic rules which built a symbolic cooperation between Hue and Intensity according to Chroma, a region growing segmentation with fuzzy aggregation is proposed. This fuzzy segmentation is compared with a technique using a Fuzzy C-Means algorithm in different colour spaces.

*Key words:* Colour segmentation - Fuzzy sets - Knowledge integration.

## 1 INTRODUCTION

For a few years, there is a growing interest in using a linguistic approach associated with fuzzy subsets theory for image processing. This is true in high level processing (interpretation) but also in low-level processing (filtering **[1]**, segmentation **[2][3]** or edge detection- in **[8]** a fuzzy colour edge extractor by *If-Then* rules operating in Hue, Chroma, Intensity (HCI) space has been presented).

In the case of colour image segmentation, the Fuzzy C-Means (FCM) algorithm **[4]** is widely used for clustering **[5][6][7]**. However, it is also widely recognized that the clustering technique based on FCM suffers from problems related to adjacent clusters frequently overlapped in colour space, inducing incorrect pixel classification. Furthermore, clustering is more difficult when the number of clusters is a priori unknown, which is typical in segmentation application. An other inconvenient of these methods is that they don't take into account the specificity of the colour image.

There are different methods to get HCI representation from RGB space. In this paper, the colour used features are calculated by the following formula:

- $I = Y$
- $C = \sqrt{C_1^2 + C_2^2}$

$$\begin{bmatrix} Y \\ C_1 \\ C_2 \end{bmatrix} = \begin{bmatrix} 0,33 & 0,33 & 0,33 \\ 1 & -0,50 & -0,50 \\ 0 & -0,87 & -0,87 \end{bmatrix} \times \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

- if $C_2 > 0$ then $H = \mathrm{acos}(C_2 / C)$
  else $H = 2\Pi - \mathrm{acos}(C_2 / C)$

Of course the first interest of this space is that it is more suited to color perception than the RGB space. The second interest is that the noise sensitivity presents interesting properties **[9]**. So, Hue noise sensitivity, and consequently Hue relevance, is depending on Chroma level. This can be traduced in linguistic rules by:

- *If the Chroma is low then the Hue is hence irrelevant,*
- *If the Chroma is medium then the Hue is weakly relevant*
- *If the Chroma is high then the Hue is very relevant and its sensitivity to noise is lower than that of the Intensity.*

Thus, a segmentation algorithm in HCI space can used this specific characteristic of Hue by realizing a cooperation between Hue and Intensity according to the Chroma:

- *If the Chroma is low then Intensity is used,*
- *If the Chroma is high then Hue is used,*
- *If the Chroma is medium then Hue and Intensity are jointly used.*

So, in a region-growing segmentation, the part of the Hue component in the decision of aggregation will be nil, lower, identical, or more important than the one of the Intensity.

The basis of this work is the definition of fuzzy sets characterizing the three numerical magnitudes used in the proposed colour segmentation method, i.e. the Chroma levels of two neighbouring pixels and their Hue and Intensity difference. Then several linguistic rules are defined to integrate the specific characteristic of the Hue. These rules create a fuzzy homogeneity criterion in order to realize the fuzzy aggregation of these pixels.

In a first part a general description of the fuzzy aggregation is done. Then the fuzzy partitions of the domains are presented. The linguistic rules for the segmentation Hue-Intensity / Chroma are described in the section 4. Finally, a comparative application on biomedical images is performed.

## 2 GENERAL DESCRIPTION OF THE ALGORITHM

The segmentation technique used in this paper is a local iterative region-growing adapted from gray level images segmentation (Blob Colouring with a L-shaped template of three pixels) **[10]**. The basic idea is the definition of homogeneity criterion between two neighbouring pixels. The

criterion is a difference between features of these two pixels which are labelled to the same region if the criterion is lower than a threshold.
In our case, let us consider two pixels A and B of Chroma level $C_A$and $C_B$ with ΔI (respectively ΔH) the numerical difference of Intensity (respectively Hue). The principle of the fuzzy aggregation is described by the following schema:

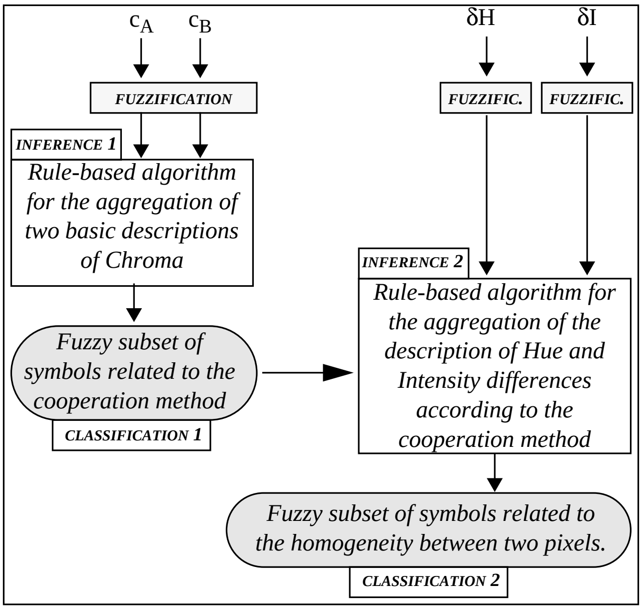


*Fig. 1* Schema of the algorithm

Before inferring the different rules we proposed, we have to realized the numeric to symbolic conversion which is called fuzzification.
Then, the first step of the algorithm is to get a classification (denoted 1 in fig. 1) of the cooperation method between Hue and Intensity according to the fuzzy linguistic description of the two Chroma. This classification is generated by a rule-based algorithm which integrated the linguistic knowledge of Hue relevance.
The second step is to obtain a classification (2 in fig. 1) of the homogeneity between the two pixels according to the previous classification and the fuzzy linguistic description of the Hue difference and the Intensity difference.
The final step is the decision of aggregation (or not) between the two pixels. This decision is taken according the preponderant homogeneity degree.

# 3 FUZZY PARTITION OF THE DOMAINS

## 3.1 Fuzzy partition of the Chroma

There is two steps to get the fuzzy partition of the Chroma.

The first one is to characterize the Hue relevance by a generic symbol "*RELEVANT*". According to the rules presented in the introduction, the membership function $\mu_{RELEVANT}(C)$ associated to this symbol is built on the discrete universe of discourse [0,255] of the Chroma as shown in Fig. 2.
The evolution of the membership function is controlled by two parameters. $C_M$ corresponds to the medium relevance of the Hue, and θ is the slope at $C_M$.

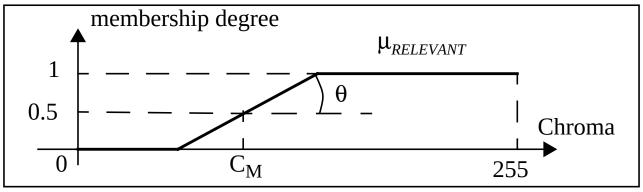


*Fig. 2* Membership function of the symbol "*RELEVANT*"

The second step is to realize a modulation of this generic symbol in order to obtain four new symbols. Thus, the linguistic partition of the Chroma is realized with the set:

*L*(C)={***GRAY, PASTEL_L, PASTEL_H, PURE***},

which will describe the Hue relevance as following:

- ❑ *GRAY*: Hue is <u>*irrelevant*</u> and must not be used.
- ❑ *PASTEL_L*: Hue is <u>*weakly*</u> relevant.
  The segmentation process will privilege Intensity.
- ❑ *PASTEL_H*: Hue is <u>*sufficiently*</u> relevant.
  The process will used jointly Intensity and Hue.
- ❑ *PURE*: Hue is <u>*completely*</u> relevant.
  The segmentation process will only use this component.

The membership functions associated to these symbols are generated from the membership function $\mu_{RELEVANT}$ as shown in Fig. 3.

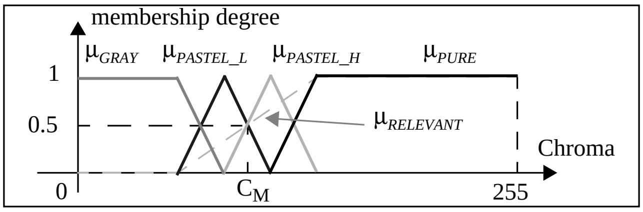


*Fig. 3* Example of fuzzy partition of the Chroma

## 3.2 Fuzzy partition of the Intensity difference

The absolute difference ΔI between two Intensity levels is ranging from 0 to 255. It is classically characterized by three symbols:

*L*(ΔI) = {***SMALL, MEDIUM, LARGE***}

and by the three membership functions associated to these symbols. This partition is built up with two parameters: Δ_Intensity_min and Δ_Intensity_max as shown in Fig. 4.

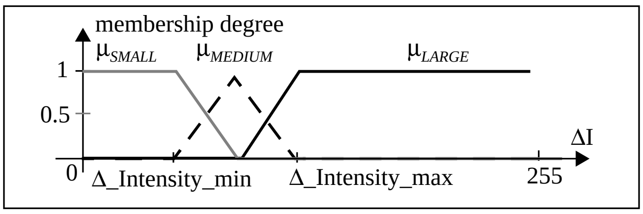


*Fig. 4* Example of fuzzy partition of the Intensity difference

## 3.3 Fuzzy partition of the Hue difference

The absolute Hue difference ΔH, which is ranging from 0 to 128 because of the circular representation of the Hue component, is also described by three symbols:

*L*(ΔH) = {***SMALL, MEDIUM, LARGE***}.

Their membership functions are build up with two parameters: Δ_Hue_min and Δ_Hue_max, just as the symbols related to the Intensity difference were defined.

## 4 LINGUISTIC RULES FOR THE HI/C SEGMENTATION

### 4.1 Rule-base for the aggregation of two basic descriptions of Chroma

Using the two fuzzy sets of the Chroma, the inference (denoted 1 in Fig. 1) produces a fuzzy subset characterizing the different possible cooperation methods between Hue and Intensity. A set of six symbols are used to classify:

$$M = \{INT, INT\_hue, INT\_HUE, int\_HUE, HUE, SEP\}.$$

The meaning of these symbols is:

- *INT*: The segmentation process uses only the Intensity.
- *INT_hue*: The Intensity component is privileged.
- *INT_HUE*: The two components are jointly used.
- *int_HUE*: The Hue component is privileged.
- *HUE*: The segmentation process uses only the Hue.
- *SEP*: Chroma values are so different that the two pixels must be separated.

This fuzzy subset is generated by a rule-based developed by expertise. The base contains 16 linguistic If-Then rules:

| | | | | |
|---|---|---|---|---|
| ❶ | If $c_A$ is *GRAY* | **and** $c_B$ is *GRAY* | Then | *INT* |
| ❷ | If $c_A$ is *GRAY* | **and** $c_B$ is *PASTEL_L* | Then | *INT* |
| ❸ | If $c_A$ is *PASTEL_L* | **and** $c_B$ is *GRAY* | Then | *INT* |
| ❹ | If $c_A$ is *PASTEL_L* | **and** $c_B$ is *PASTEL_L* | Then | *INT_hue* |
| ❺ | If $c_A$ is *PASTEL_L* | **and** $c_B$ is *PASTEL_H* | Then | *INT_hue* |
| ❻ | If $c_A$ is *PASTEL_H* | **and** $c_B$ is *PASTEL_L* | Then | *INT_hue* |
| ❼ | If $c_A$ is *PASTEL_H* | **and** $c_B$ is *PASTEL_H* | Then | *INT_HUE* |
| ❽ | If $c_A$ is *PASTEL_H* | **and** $c_B$ is *PURE* | Then | *int_HUE* |
| ❾ | If $c_A$ is *PURE* | **and** $c_B$ is *PASTEL_H* | Then | *int_HUE* |
| ❿ | If $c_A$ is *PURE* | **and** $c_B$ is *PURE* | Then | *HUE* |
| ⓫ | If $c_A$ is *GRAY* | **and** $c_B$ is *PASTEL_H* | Then | *SEP* |
| ⓬ | If $c_A$ is *GRAY* | **and** $c_B$ is *PURE* | Then | *SEP* |
| ⓭ | If $c_A$ is *PASTEL_L* | **and** $c_B$ is *PURE* | Then | *SEP* |
| ⓮ | If $c_A$ is *PASTEL_H* | **and** $c_B$ is *GRAY* | Then | *SEP* |
| ⓯ | If $c_A$ is *PURE* | **and** $c_B$ is *GRAY* | Then | *SEP* |
| ⓰ | If $c_A$ is *PURE* | **and** $c_B$ is *PASTEL_L* | Then | *SEP* |

The inferred fuzzy partition, which classified the cooperation method (denoted classification 1 in Fig. 1) is calculated by a mechanism of conjunction and aggregation of these rules.

The expression of each rule generates an elementary membership degree for the inferred symbol by a mechanism of conjunction. We chose the multiplication as fuzzy "**and**" operator of conjunction.

Then, a fuzzy "**or**" operator is used to aggregate all the elementary membership degrees of an inferred symbol in order to obtain the final membership degree of this symbol according to Chroma inputs. In our case, we chose the bounded sum to 1 as operator of disjunction.

We chose these two operators because they are less sensitive to noise than the "min" operator (conjunction) and the "max" operator (disjunction).

Thus, for example, rules ❸, ❹ and ❺ give three elementary membership degrees for the symbol *INT_hue* by:

❸ $\mu^3_{INT\_hue}(c_A, c_B) = \mu_{PASTEL\_L}(c_A) * \mu_{PASTEL\_L}(c_B)$,
❹ $\mu^4_{INT\_hue}(c_A, c_B) = \mu_{PASTEL\_L}(c_A) * \mu_{PASTEL\_H}(c_B)$,
❺ $\mu^5_{INT\_hue}(c_A, c_B) = \mu_{PASTEL\_H}(c_A) * \mu_{PASTEL\_L}(c_B)$,

Then, the final membership degree is obtained by:

$$\mu_{INT\_hue}(c_c, c_B) = \max(1, \mu^3_{INT\_hue} + \mu^4_{INT\_hue} + \mu^5_{INT\_hue})$$

This membership degree can be regarded as an applicability degree associated to the cooperation method *INT_hue*.

### 4.2 Rule-base for the classification of the homogeneity between two pixels according to the cooperation method.

Using a fuzzy subset characterizing the cooperation method and two fuzzy subsets of difference (for Hue and Intensity), the inference (denoted 2 in Fig. 1) produces a fuzzy subset which classified the homogeneity between two pixels (classification denoted 2 in Fig. 1). Two symbols are used to classify the homogeneity:

$$Q = \{HOMOGENEOUS, HETEROGENEOUS\}.$$

For each of the 6 fuzzy cooperation methods previously presented a fuzzy rule using differently the fuzzy differences in Hue and in Intensity is developed. Thus, the rule-base contains 6 *If-Then-Else* rules:

❶ If the method is *INT* **and**
  If $\delta I$ *is SMALL* Then *HOMOGENEOUS*
  Else *HETEROGENEOUS*

❷ If the method is *INT_hue* **and**
  If $\delta I$ is *SMALL* **and** $\delta H$ is *(SMALL* **or** *MEDIUM)* Then *HOMOGENEOUS*
  Else *HETEROGENEOUS*

❸ If the method is *INT_HUE* **and**
  If $\delta I$ is *SMALL* **and** $\delta H$ is *SMALL* Then *HOMOGENEOUS*
  Else *HETEROGENEOUS*

❹ If the method is *int_HUE* **and**
  If $\delta I$ is *(SMALL* **or** *MEDIUM)* **and** $\delta H$ is *SMALL* Then *HOMOGENEOUS*
  Else *HETEROGENEOUS*

❺ If the method is *HUE* **and**
  If $\delta H$ is *SMALL* Then *HOMOGENEOUS*
  Else *HETEROGENEOUS*

❻ If the method is *SEP* Then *HETEROGENEOUS*

The membership degree $\mu_{HOMOGENEOUS}$ and $\mu_{HETEROGENOUS}$ associated to symbols *HOMOGENEOUS* and *HETEROGENEOUS* are obtained by inferring all these rules by a similar mechanism as in 4.1. In each rule, the conjunction is realized by a fuzzy "**and**" operator. Then, for each elementary membership degrees of an inferred symbol, the fuzzy "**or**" operator is used.

The final decision of aggregation or not between the two pixels is taken according to the maximum between the membership degree $\mu_{HOMOGENEOUS}$ and $\mu_{HETEROGENOUS}$.

## 5 APPLICATION ON BIOMEDICAL IMAGE

In these two colour biomedical images, the goal is to conserve, after segmentation, the nucleus of the cells artificially indicated by a white circle in original images.

Our segmentation algorithm (call ***Fuzzy_segm_HI/S***) is compared with the algorithm presented by Lim [7]. This algorithm segments an image by analysing the histograms of the color components and identifying units that are homogeneous with the fuzzy c-means technique. The scale-space filter analyses the histograms of the three color components of the image and identifies a set of classes. The extents of each class is used to coarsely segment the image with thresholding. The color associated with each class is determined by the mean color of all pixels within the extents of a particular class. Finally, any unclassified pixels are assigned to the closest class with the fuzzy c-means technique. It can be used in different color spaces, such as for example the YUV space or the $I_1I_2I_3$ space defined by Ohta [11].

## 6 CONCLUSION

According to the realised study, the colour region-growing segmentation in HCI space with fuzzy aggregation provides a better detection of the regions than a technique using thresholding and Fuzzy C-Mean in others colour spaces.

More generally, using fuzzy subsets for characterizing numerical magnitudes allows to aggregate these magnitudes without any modification of their signification, even if they are semantically different.

The great flexibility given by the symbolic representation and by the use of rules is an other interest of the proposed method. The fusion of the colour features is then designed in a natural way. Further more, thanks to the linear shape of the membership functions, the performances are robust against little changes of the parameters values.

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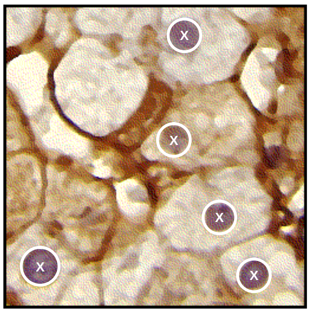
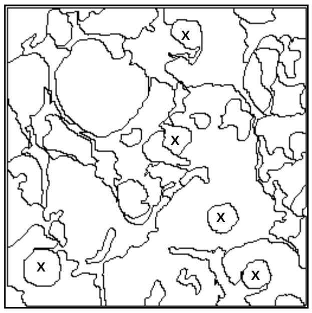
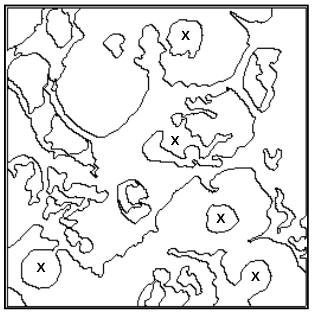


a] ***Original image***

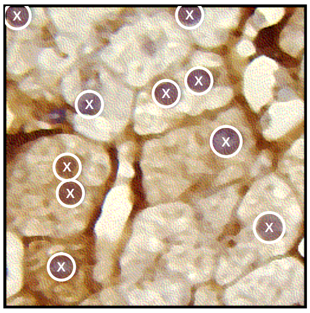


b] ***Fuzzy_segm_HI/S***

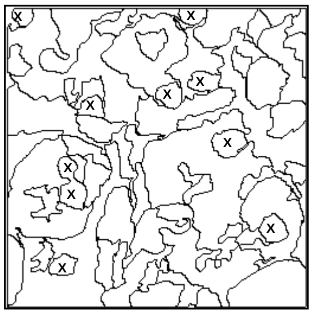
c] ***Lim’s Algorithm working in YUV space***



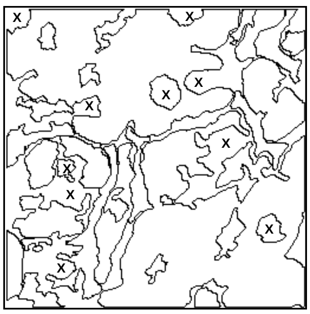
d] ***Lim’s Algorithm working in*** $I_1$ $I_2$ $I_3$ ***space***



e] ***Original image***



f] ***Fuzzy_segm_HI/S***



g] ***Lim’s Algorithm working in YUV space***

h] ***Lim’s Algorithm working in*** $I_1$ $I_2$ $I_3$ ***space***