

# A Contribution to Ancient Cadastral Maps Interpretation through Colour Analysis

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**Abstract.** In this paper, a colour graphic document analysis is proposed with an application to ancient cadastral maps. The approach relies on the idea that images of document are fairly different than usual images, such as natural scenes or paintings... From this statement, we present an architecture for colour document understanding. It is based on two paradigms. Firstly, a dedicated colour representation named adapted colour space which aims to learn the document specificity and secondly a document oriented segmentation using a region growing algorithm supervised by a hierarchical strategy. Experiments are performed to judge the whole process and the first results show a good behaviour in term of information retrieval.

## 1 Introduction

The extraordinary potential of the automatic analysis of colour documents brings new interests and represents a real challenge since colour has always been considered as a strong tool for information extraction [1]. In the context of a project called “ALPAGE” supported by the French National Research Agency (ANR)[14], we are considering the digitalization of ancient maps. In this ALPAGE project, we consider cadastral maps from the 19th Century (called “Atlas VASSEROT”), on which objects are drawn by using colour to distinguish parcels for instance. This project deals with the classical graphic recognition problems, to which are added difficulties due to the presence of colours and strong time due degradations of relevant information : colour degradation, yellowing of the paper, pigment fading... In the context of this pluridisciplinary project, the idea is to provide strategic information for historians, or students, what means that the purpose is to propose a set of processing allowing to segment/recognize all the objects of the documents. In such a topic, the number of handled objects can be counted by million. This volume of data leads to the rise of new services as intelligent indexation, document browsing and content searching. These subjects lead us to the implementation of mutualized working tools for both ICT-HSS communities (Information/Communication Technologies – Human/Social Sciences), allowing to develop research relating to urban space, namely, PRAI software (Pattern Recognition and Adapted Intelligence) adapted to ancient cadastral maps, and a GIS (Geographical Information System) including cadastral and historical layers.

It is a new approach to the urban environment, truly integrating the spatial dimension, which could be implemented thanks to the contributions of recent disciplines such as computer vision, geomatic and archeogeography. If the analysis of a given document were reduced in the digitalization of the paper document to a “bitmap” image, the problem would be commonplace. Actually the subjacent scientific problems are very complex because the objective is much more ambitious, the conversion of the paper document into its semantic interpretation [2]. The concept of retro-conversion is a semantic digitalization, from elementary data and contextual information the analysis is carried out through a colour graphic recognition process where the aim is to build structured information dedicated to a GIS. A classical ascending approach from pixel to object calls various low level tools such as colour segmentation or line tracking while at the top, high level methods allow the integration of a priori knowledge bringing a contribution to the interpretation process with an aim of archiving information [fig 1] [3].

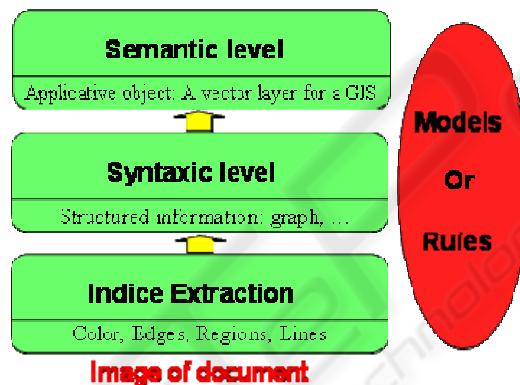


Fig. 1. Architecture of a graphic document analysis system.

Since we need to consider the colour meaning to extract cadastral information (ie: a parcel), we have to take care about the colour representation. Consequently, in this paper, we propose a general architecture to take into account colour information from graphic documents. Our method relies on three steps: firstly, finding the best colour model in terms of distinction between different colours. We assume that the choice of an efficient colour model will be decisive since the performance of any colour-dependent system is highly influenced by the colour model it uses. Secondly, a colour segmentation approach dedicated to documents is presented; it is inspired by graphic construction rules of cadastral maps. And finally, a vectorisation step [11] provides cadastral objects to be inserted into the GIS.

The paper is organized as follows: In the second section, the question of finding the best colour space is introduced. Then, the third section presents the colour segmentation working on documents, and particularly the specific operators involved. The fourth section presents the application to ancient cadastral maps, a comparative study of colour segmentation methods is given. Finally, a conclusion is given and future works are brought in section 5.

## 2 Colour Space

In the last ten years, colour analysis has known a considerable progress, due to the number of acquisition devices which provide colour information, in most of the cases. In the context of our project, as said in the introduction, the difficulty is to explore techniques issuing from the rich literature, and to try to adapt it to our very specific context of degraded colours.

### 2.1 Forewords: About Pre-processing

In introduction, we express the difficulties to analyse ancient documents which were deprecated due to the time, usage condition or storage environment. So clearly, a real need for image restoration has come up. Two pre-processing, the white patch and the faded colour correction have been executed to bring colours back to original or at least to unleashed colour significance. A good survey of them can be found in [15][16].

### 2.2 Standard Colour Space

Most of acquisition devices, such as digital cameras or scanners, process signals in the RGB format. This is why RGB space is widely used in the applications of image processing. The R primary in RGB corresponds to the amount of the physical reflected light in the red band. However, RGB representation has several drawbacks that decrease the performance of the systems which depend on it. RGB space is not uniform; the relative distances between colours do not reflect the perceptual differences. Therefore, HSI space has been developed as a closer representation to the human perception system, which can easily interpret the primaries of this space. In HSI space, the dominant wavelength of colour is represented by the hue component. The purity of colour is represented by the saturation component. Finally, the darkness or the lightness of colour is determined by the intensity component. Eq.(1) shows the transformation between RGB and HSI spaces [5].

$$\begin{aligned}
 I &= \frac{1}{3}(R + G + B) & (1) \\
 S &= 1 - \frac{3}{R+G+B}[\min(R, G, B)] \\
 H &= \begin{cases} \theta & B \leq G \\ 360 - \theta & B > G \end{cases} \\
 \text{where } \theta &= \cos^{-1} \left\{ \frac{0.5[(R-G)+(R-B)]}{\sqrt{(R-G)^2 + (R-B)(G-B)}} \right\}
 \end{aligned}$$

Although the HSI space is suitable for lots of applications based on colour images analysis, this colour space presents some problems. For example, there are non-avoidable singularities in the transformation from RGB to HSI, as shown in Eq.(1). The XYZ colour space developed by the International Commission on Illumination (CIE) in 1931 [9] is based on direct measurements of the human eye, and serves as the basis from which many other colour spaces are defined. The YUV colour is used in the PAL system of colour encoding in analogical video, which is part of television

standards. The YUV model defines a colour space in terms of one luminance and two chrominance components. Another alternative of YUV is the YIQ which is used in the NTSC TV standard. On the other hand, Ohta, Kanade, and Sakai [10] have selected a set of "effective" colour features after analyzing 100 different colour images. Those selected colour features are usually names as I1I2I3 colour model. XYZ, YUV and I1I2I3 are non-uniform colour spaces; therefore CIE has recommended CIE-Lab and CIE-Luv as uniform colour spaces, as they are non-linear transformation of RGB space [8].

### 2.3 Trained Colour Space

In [13], dominant features from different colour spaces are selected to construct "Hybrid Colour Space" (HCS). A principal component analysis is performed from the covariance matrix composed with the total number of the candidate primaries. The 3 most significant axis are selected to reduce rate of correlation between colour components. From this statement, two Genetic Algorithms (GAs) are introduced [4]. They are handled in two different ways. The first one can be seen as a feature selection algorithm to build a HCS while the second one is a learning process in order to discover coefficients/weights which will be used to compute a linear transformation of RGB, such a model is called all along this paper as adapted colour space (ACS).

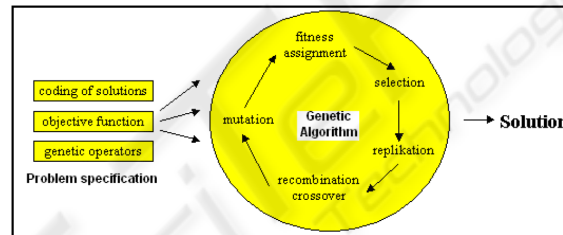


Fig. 2. Overview of a genetic algorithm.

### 2.4 Genetic Algorithm

Genetic algorithms are adaptive heuristic optimisation algorithms based on the evolutionary ideas of natural selection and genetics. The basic concept of GAs is designed to simulate natural processes, necessary for evolution of adapted systems. They represent an intelligent exploitation of a random search within a defined search space to solve a problem. As can be seen on fig 2, after a random initialization of a population of possible solutions, GA's are based on a sequential ordering of four main operators: selection, replication, crossover and mutation. In order to apply genetic algorithms to a given problem, three main stages are necessary: the coding of the problem solutions, the definition of the objective function which attributes a fitness to each individual, and the definition of the genetic operators which promote the exchange of genetic material between individuals.

## 2.5 Hybrid Colour Space Built by Genetic Algorithm

In HCS context, each individual has to encode a vector, where each component is an axis of the HCS. We consider a set  $C$  of features.  $C = \{C_i\}_{i=1}^N = \{R,G,B, I1,I2,I3, L, u,v,\dots\}$  with  $\text{Card}(C) = 25$ . Practically, it is almost impossible to test all possible combinations, since they have a combinatory number equal to the factorial of the total number of the candidate primaries, hence, GA are well suited to get a rid off absurd combination. From now, the first step is to initialize the population, each individual is made up picking randomly three elements of  $C$ . Concerning cross over operator, two individuals  $h1$  and  $h2$  share their genetic material, swapping one of their component; fig 3. Finally, to perform mutation on an individual, one component is selected and replaced at random by an element of  $C$ .

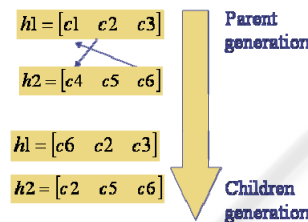


Fig. 3. HCS: cross over operator.

## 2.6 Adapted Colour Space Calculated by Genetic Algorithm Learning

In ACS context, each individual  $W$  has to encode a  $3 \times 3$  matrix, where each matrix element is a coefficient used to compute a linear transformation of RGB. Each coefficient belongs to the interval  $[-1 ; 1]$  and the initialisation is made at random.

$$\begin{bmatrix} R_s \\ G_s \\ B_s \end{bmatrix} = W \cdot \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Where  $W$  is defined as follow:

$$W = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} = \begin{bmatrix} e_1 \\ e_2 \\ e_3 \end{bmatrix}$$

And  $e_1, e_2, e_3$  are line vectors.

Concerning cross over concept, two individuals  $w1$  and  $w2$  promote their genetic material, exchanging to each other one of their component; fig 4. To perform mutation on an individual, one component is selected and replaced by a new line vector generated at random.

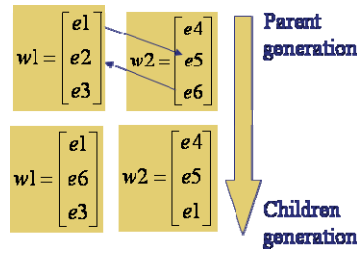


Fig. 4. ACS: Cross over operator.

## 2.7 Fitness

Both applications implement the same fitness to judge the well behaviour of a colour space. We consider a colour space as well suited if it maximises a colour recognition rate given by a supervised colour classification step.

## 3 Colour Segmentation

Colour segmentation has been a subject of research for about 40 years. Such an amount of effort cannot be resumed in few lines. Consequently, we sum up the main ideas by categorising colour segmentations into general families and then, we introduce a hierarchical growing region method adapted to cadastral maps.

### 3.1 Main Colour Segmentation Families

Image segmentation methods can be categorised as follows:

- Histogram thresholding: assumes that images are composed of regions with different color ranges, and separates it into a number of peaks, each corresponding to one region.
- Edge-based approaches: use edge detection operators such as Di Zenzo[6] for example. Resulting regions may not be connected, hence edges need to be joined.
- Region-based approaches: based on similarity of regional image data. Some of the more widely used approaches in this category are: Thresholding, Clustering, Region growing, Splitting and merging.
- Hybrid: consider both edges and regions.

### 3.2 Region Growing Segmentation Supervised by a Hierarchical Strategy

An initial set “A” of small areas are iteratively merged according to similarity constraints and according to a hierarchical order. Roughly, seeds are localized where the color gradient is low and from the starting point, we start by choosing the seed pixel with the lowest intensity and compare it with neighbouring pixels.








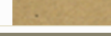
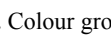
Then, region is grown from the seed pixel by adding in neighbouring pixels that are similar, increasing the size of the region. When the growth of one region stops we simply choose the next seed pixel which fulfill both constraints, does not yet belong to any region and a low intensity level. This whole process is continued until all pixels belong to some region. Region growing methods[7] often give very good segmentations since it is using both concepts color homogeneity and spatial aspect. The choice of organizing the growing region according to the intensity of the pixel seeds is motivated by the will of considering the document layout. Dark areas such as lines or dark sections are meaningful and represent the frame of the graphic organisation. And it is helpful in order to materialize the relations between lighter regions.

## 4 Application to Ancient Cadastral Maps

In this part, we present results on colour space analysis, and colour document segmentation with an application to ancient cadastral maps.

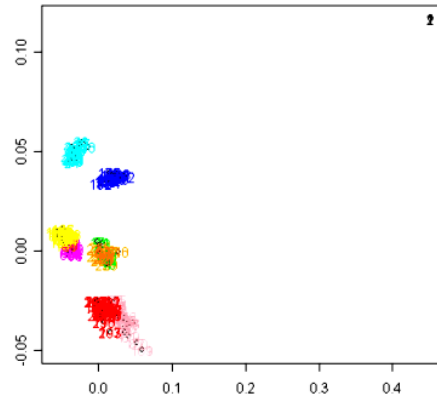
### 4.1 Experiments on Colour Spaces

To evaluate the suitability of a colour space, we define a colour ground truth. We work with two data bases. One is used for learning process dedicated to HCS and ACS and the other one is applied in a validation context. In all colour spaces, we perform a KNN classification based on a Euclidian metric to obtain the corresponding colour recognition rates.

	RGB Colors	Names for displaying
Class 1		black
Class 2		green
Class 3		cyan
Class 4		magenta
Class 5		pink
Class 6		Yellow
Class 7		blue
Class 8		red
Class 9		orange

**Fig. 5.** Colour ground truth.





**Fig. 6.** Colour data: 2D projection using one form of non-metric multidimensional scaling[12].

**Table 1.** Colour recognition rate obtained by colour classification.

Color Space	Rate	Color Space	Rate
RGB	0,7112	ISH	0,6149
III2I3	0,7112	La*b*	0,6417
XYZ	0,6737	Luv	0,6577
YIQ	0,7058	Adapted Space	<b>0,7647</b>
YUV	0,6791	PCA Space	0,7005
AC1C2	0,6684	HybridSpace	<b>0,7326</b>

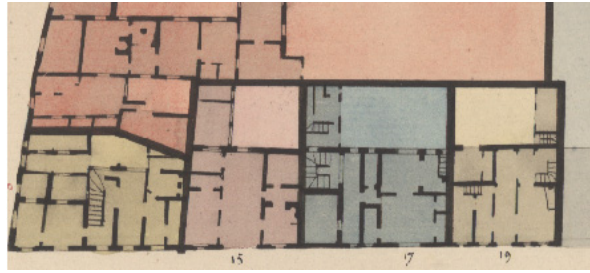
In table 1, the good results of trained colour spaces HCS and ACS illustrate the need of dedicated colour spaces when we deal with colour graphic documents.

We are brought to conclusion that colour images of documents are like no others, we mean very specifics and far away from natural scene. Hence, we point out the need of an adapted colour space.

#### 4.2 Segmentation Results using Region Growing Algorithm Supervised by a Hierarchical Scenario.

This experiment is carried out starting from the original RGB image [fig 7] to which we apply the ACS transformation. From this point, the construction of region is performed according to the scenario described in 3.2. At the end of this operation, we return to RGB representation computing the transformation inverse of ACS ( $W^{-1}$ ). We obtain the segmented image [fig 8] where the found regions will be used to create cadastral objects.





**Fig. 7.** A piece of cadastral map in RGB space.



**Fig. 8.** A segmented image by our approach.

## 5 Conclusion

In this paper, we have been interested in an original problem, the colour graphic document analysis with an application to ancient cadastral maps. Our contribution concerns a processing chain which is based on a trained colour space and hierarchical growing region segmentation. Both tools are colour document oriented to consider the graphic properties of documents. We are completely aware that works have to be done to compare results to others approaches. However, preliminary results of our starting project show a meaningful segmentation for interest regions on cadastral maps. In addition, research perspectives are explored to combine/fusion black and colour layers for reaching the interpretation result.

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