The importance of color spaces in robotic vision

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Abstract

Autonomous robots are becoming an integrated part of our daily life. The use of a robot for substituting the man power in different activities that might be too dangerous, repetitive or too time consuming, has become a common procedure nowadays. From autonomous vacuum cleaners, to autonomous robotic platforms used in industry, autonomous robotic space explorers and even autonomous robotic companions, robots are being developed with the purpose of imitating and improving some of the most basic human capabilities. Imitating human capabilities implies, in most applications, the implementation of a digital alternative for most of the sixth human senses. The implementation of an artificial visual sense for a robot is a research challenge that has not been yet overcomed. In robotic applications that require a vision system, it is common that the artificial visual sense of the robot be the most important sense, on which all the other capabilities of the robot are based. A significant number of robotic vision systems base their functioning logic on the color information of the surrounding world. An important step in the process of “teaching” a robot the meaning of colors, is the choice of a proper color space, that could ease this task. This paper intends to be a study on the most common color spaces used in robotic applications and presents some preliminary results of an application developed with the purpose of finding the most appropiate color space to be used when implementing robotic vision systems.

1 Introduction

In the last years, autonomous robotics has been a research field under continuous evolution and expansion. Autonomous robots are being built with the purpose of easing the life of the humans, either by taking over some of the most difficult and repetitive chores of their daily life activity, or by assisting the ones with special needs. Probably the most important sense that a robot should possess in order to be able to perform its tasks in an uncontrolled environment and in un unmanned manner, is the visual sense, by means of which it should perceive the surrounding world. The human brain can process all the visual information provided by the eyes in a short amount of time since it possesses 10^{10} neurons, out of which, some have over 10000 synapses with other neurons [3]. Looking at each neuron as a microprocessor and considering that these microprocessors are able to work in parallel, the human CPU cannot even be compared to any computer that has been invented so far. Thus, providing a visual sense similar to the human one, to a robot, is yet a far to be accomplished task. Because of this, most of the robotic platforms that are being developed nowadays and that need to process visual information about the surrounding world, perform in environments that are controlled up to a certain extent, depending on the practical application of the robot.

In many industrial applications, as well as in research scopes, the processing of the visual information of a robot has as a first step, a color segmentation procedure. Especially in controlled environments, color can be an important clue for the detection of an object of interest. The color segmentation procedures imply the definition of color ranges for all the colors of interest of the application. Defining color ranges can be done by a human user, as an offline procedure, prior to the performance of the robot or it can be done online, by using automatic algorithms. The representation of the colors in digital format depends on the color space chosen. In this paper we present the preliminary results of a study on the use of color spaces in robotic vision, in order to understand if there is a more appropriate one to be used in these kind of applications. A tool for defining color ranges, both by a user and by an automatic algorithm of region growing, under different color spaces has been developed and some preliminary results have been obtained so far.

This paper is structured in five sections, the first of them being this introduction. Section 2 provides an overview on the color spaces that have been included in the testing platform. In Section 3 some preliminary results and their discussion are presented. Finally, Section 4 concludes the paper and outlines the future directions of this application.

2 Color Spaces

For the purpose of this study, four different color spaces will be studied. A color space is a mathematical model for representing the notion of color in the digital world. The conversions between these four color spaces are based on linear mathematic equations. Each of the color space has emerged at some moment in the history due to necessity of rendering images on different devices or with different infrastructures. The study that the authors are proposing, aims at finding the most appropriate color space for robotic applications.

The RGB color space 1 is the most convenient one to work with in computer graphics since it is the closest to the way the human eye works. A RGB color space is an additive color space, defined by the three chromaticities of the red, green, and blue. The main purpose of the RGB color model is for the sensing, representation, and display of images in electronic systems, such as televisions and computers, though it has also been used in conventional photography [1].

Before the electronic age, the RGB color model already had a solid theory behind it, based in human perception of colors. To form a color with RGB, three colored light beams (one red, one green, and one blue) must be superimposed (for example by emission from a black screen, or by reflection from a white screen). Each of the three beams is called a component of that color, and each of them can have an arbitrary intensity, from fully off to fully on, in the mixture. The RGB color model is additive in the sense that the three light beams are added together, and their light spectra add, wavelength for wavelength, to make the final color’s spectrum.

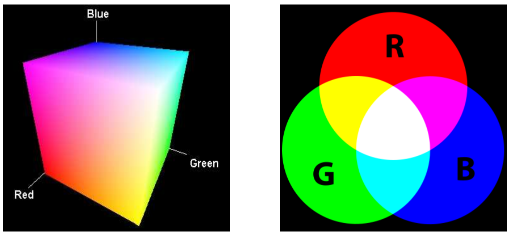

Figure 1: On the left, the RGB cube and on the right, an example of an additive color mixing: adding red to green yields yellow, adding all three primary colors together yields white [4].

The HSV color space is a related representation of points in an RGB color space, which attempts to describe perceptual color relationships more accurately than RGB [1, 2]. HSV stands for hue, saturation, value and it describes colors as points in a cone whose central axis ranges from black at the bottom to white at the top (Fig. 2) with neutral colors between them, where angle around the axis corresponds to “hue”, distance from the axis corresponds to “saturation”, and distance along the axis corresponds to “value”, “lightness”, or “brightness”. The hue represents the percentage of color blend, the saturation the strength of the color and the value is the brilliance or brightness of the color.

The HSV color space is mathematically cylindrical, but it can be thought of conceptually as an inverted cone of colors (with a black point at the bottom, and fully–saturated colors around a circle at the top). Because

HSV is a simple transformation of device–dependent RGB, the color defined by (h, s, v) triplet depends on the particular color of red, green, and blue “primaries” used. Each unique RGB device therefore has an unique HSV space to accompany it.

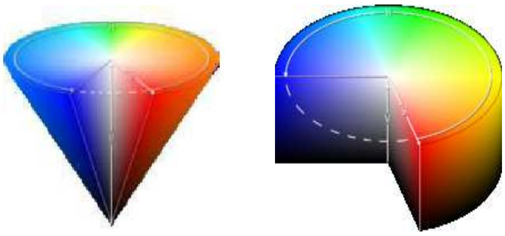

Figure 2: The conical and cylindrical representations of the HSV color space [4].

The HSL color space is similar to the HSV one, the definition of hue and saturation, being the same as for the HSV color space. The “value” component is replaced by “lightness” and the main difference is the fact that the value, or the brightness of a pure color is considered to be the brightness of white, whereas tehe lightness of a pure color is the lightness of medium gray. The geometrical representation of the HSL color space is a double cone or double hexcone 3.

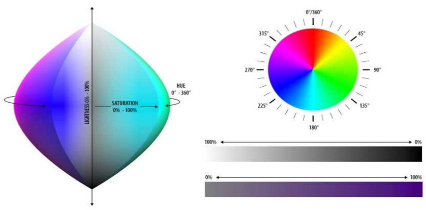

Figure 3: The geometrical representation of the HSL color space.

In the YUV color space 4, the color is represented in terms of a luminance component (Y stands for luma) and two chrominance, or color, components (U and V). This color space appeared as a necessity of introducing color television using a black and white infrastructure and encodes a color image also taking the human perception into consideration, that is, separating the luminance information by the color information.

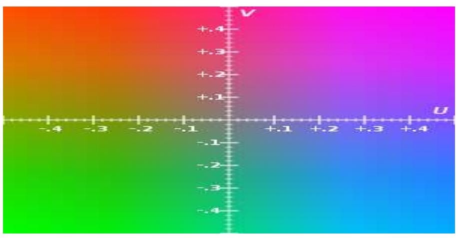

Figure 4: Geometrical representation of U-V color plane, when Y = 0.5 [4].

3 Results and Comments

In this section, some preliminary results obtained with the Color Spaces Tool 5 will be presented and commented.

The tool has been developed for the study of color spaces when performing manual color classification, as well as for studying the same color spaces when using semi-automatic color segmentation algorithms, or what the user call as supervised color classification. For the supervised color classification, several region growing algorithms have been implemented and the user only has to select a starting pixel (or a seed point) for each of the color that he wants to be classified.

For the manual classification task, the users were given an image containing different colored objects 6 and their task was to manually define, with the help of sliders, color ranges for all the colors in the image and for all the mentioned color spaces. They were asked to take notes about their performance time, as well as about the correctness of their classification.

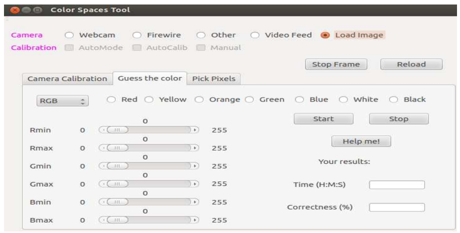

Figure 5: Illustration of the Color Spaces Tool.

The correctness is calculated by direct comparison with a ground truth classified image, previously created by an experienced user.

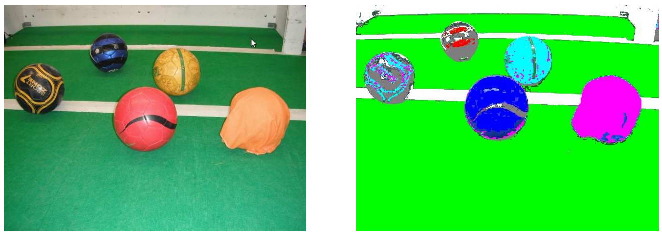

Figure 6: On the left, an example of an image used for testing manual color classification. On the right, the ground truth image used for comparing the results of the classification.

At the end of the trial, the subjects were also asked to fill in a questionnaire that would help the authors understand if there is any preferred or easier to use color space. The results show so far that the users performed faster and achieved better results in the HSV and HSL color spaces, while the RGB and YUV ones were more difficult to handle. The gathering of the results is still on-going since a large number of subjects is needed in order to have a strong conclusion at the end of the process.

4 Conclusions and Future Work

This paper presented the preliminary results of a study on the importance of color spaces in a robotic vision system. Three major issues that this study tries to address are the influence of a color space on the processing time of a color segmentation algorithm, the amount of time spent by a human user for classifying colors under different color spaces, as well as number of pixels correctly classified both manually or automatically, under the same color spaces. The collection of results for multiple human users is still in process, therefore the most important future direction is gathering these results and reaching a final conclusion about the influence of the color spaces.

5 Aknowledgements

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