MIPS Lab

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Abstract. The MIPS Lab of the University of Milan, established in 2015, focuses on the relationship between man and technology, with focus on the four points of its acronym: Multimedia, Interaction, Perception and Society.
Multimedia, with its own lab called "I've seen things" is focused on digital film restoration and preservation, with attention to film degradation, color analysis and correction and digital data management. One of the main research topics is unsupervised digital movie restoration with spatial models of colors.
The Interaction part focuses on the study of Human-Computer Interaction. Particularly, we are active in National and International projects aimed at developing interactive multimodal systems in different domain contexts, especially in the field of smart cities, smart home, IoT and conversational design.
Research on Perception is aimed at having a better understanding on how the human visual system works, by studying and modeling the retina and its functioning, including issues related to Color Vision Deficiencies, exploring the retinal-cortical color theory with Spatial Color Algorithms (SCAs), studying and experimenting with Glare and High Dynamic Range.
Society, now inactive due to retirement of the professor in charge, used to perform research and development of platforms for open government, e-participation, e-democracy and digital citizenship.

Keywords: Color Vision, Image Enhancement, High Dynamic Range Imaging, Visual Perception, Retina and Vision Modeling, Film Restoration, Human-Computer interaction

1 Introduction

The research activity of the MIPS Laboratory is constituted by four distinct but interrelated sections which have their research focus on Multimedia, Interaction, Perception, and Society, represented in the logo in Figure 1. The laboratory was established in 2015 by professor Alessandro Rizzi and is based on a long history of research carried on by current and former members.

The research of MIPS in Multimedia field is carried on by a new laboratory called "I've Seen Things" (Figure 2). It focuses on the study of digital film restoration and preservation, image enhancement, digital imaging and color. We have proposed an alternative approach to the standard digital color film restoration, based on the idea of recovering the appearance of color rather than the original color signal, since in most cases a physical color restoration is not possible due to the lack of original reference or to severe gamut constraints induced by non-available original media. Our described approach is based in the application of Spatial Color Algorithms (SCAs) [1-2].

Research in the Interaction field focuses on the study of Human-Computer Interaction. We are active in National and International projects aimed at developing interactive multimodal systems in different domain contexts, especially in the field of smart cities, smart home, IoT and conversational design.

Our research on Perception is aimed at having a better understanding on how the human visual system works, by studying and modeling the retina and its functioning [3], developing the retinal-cortical color theory with SCAs [4-27], carrying on studies and experiments on Glare and High Dynamic Range [28-34].

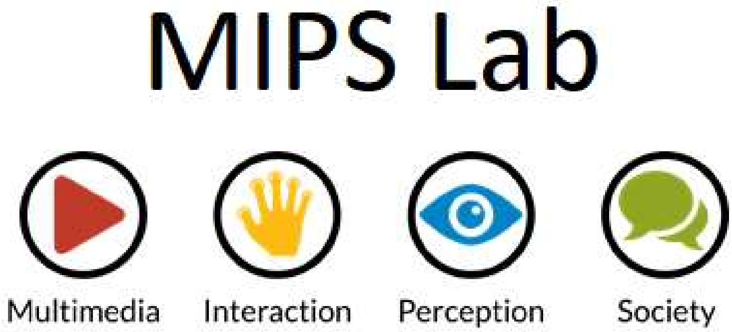

Fig. 1. Logo of the MIPS Lab

2 Multimedia

Movies are now universally considered as part of human cultural heritage. However, color films are subject to the aging of the support and especially of the dyes contained in the emulsion. This decay is a natural process that usually introduces a color dominant, loss of contrast and/or color desaturation. If not restored, a large part of the film cultural heritage will be lost relatively quickly, hence the strong ethical obligation to preserve and restore those moving images that represent our social memory.

Thanks to the relevant technical progresses of the last years, the digital restoration of color has widely spread, replacing classic photochemical and optical tools applied directly on the original film materials. With the transition to digital restoration, removing color cast is easier, allowing equalization of the frame histogram, expansion of the dynamic range and adjustment of desaturated colors. Even if digital techniques easily allow multiple attempts, they still are manual or semi-automatic delicate operations performed under constant supervision of qualified personnel. Current state of the art in digital restoration is mainly based on color grading techniques: "primary" grading affects the levels of RGB, gamma, shadows and highlights in the entire frame, while "secondary" techniques apply changes only on a selected range of colors or windows in the frame.

Fig. 2. Logo of the I've Seen Things Lab

Our proposed alternative approach to the standard digital color film restoration is based on the idea of recovering the appearance of color rather than the original color signal, by the application of SCAs to the digital signal. SCAs are a family of algorithms inspired by the capabilities of the Human Vision System (HVS) to autonomously adjust to the variations of color and lightness in the scene and are widely used for general-purpose enhancement of digital images.

This approach can be used both for complete restorations or as unsupervised kick-start process, followed by further manual refinements. The advantage of using SCAs is that they are aimed at automatically adjusting the strength of correction according to the level of enhancement required by the input. [1, 2]

To test SCAs, we proposed Image Databases characterized by the introduction of different backgrounds with a wide frequency range, a set of different illuminants (natural and artificial), and images with and without casted shadows: YACCD (Yet Another Color Constancy Database) and YACCD2 (Yet Another Color Constancy Database Updated): a renewed version of YACCD with new features in order to make it more suitable to test a wider variety of visual and image processing algorithms.

3 Perception

The Perception section of MIPS Lab has its origins in the Eidomatics Laboratory, established by Prof. Daniele Marini, and the Perception, Human Factors and Technology Laboratory, established by Prof. Alessandro Rizzi at Università degli Studi di Milano.

The main research directions about perception are three:

- High Dynamic Range (HDR) imaging
- Spatial Color Algorithms (SCA) and human vision and appearance modeling
- Spatial and functional models of human retina

3.1 High Dynamic Range (HDR) imaging

High Dynamic Range (HDR) imaging is a very active area of research today, and the consumer market is distributing everywhere (so called) HDR devices, but still there is no agreed solution and standard.

The main reason of this point is that HDR behavior is ruled by its inner limits. If one wants to grasp the underlying mechanisms of HDR needs to study the limits that occurs in the acquisition, in the reproduction and in the viewing of HDR scenes and visual contents. Our lab started more than 10 years ago in exploring these limits [28-30].

These experiments and the following studies have led to two books and other works [31-33] presenting the strong relationship between a general solution for HDR and the Human Vision System (HVS), topic of the following subsection.

3.2 Modeling human vision and appearance, Spatial Color Algorithms

Color sensation is not directly linked to the spectral or colorimetric characteristics of the signal at a point. With the same triplet of stimuli, almost any color sensation can be reproduced ("Yet, when we measure the amounts of light in the world around us, or when we create artificial worlds in the laboratory, we find that there is no predictable relationship between flux at various wavelengths and the color sensations associated with objects." [4]).

The term "Spatial Color" refers to a family of algorithms that recompute wavelength/energy arrays into calculated color appearance arrays, or preferred color enhancement arrays, according to the spatial distribution of pixel values in the scene. They can be used for modeling HVS or simply for unsupervised image enhancement.

The starting algorithm of this family is Retinex [4].

The idea at the base of Retinex, a contraction of the words retina and cortex, is that these two parts of human body, which compose our vision system, realize a robust adjustment to compensate for the high photometric and colorimetric variability of the world around us. This is realized by spatial comparisons within the various areas of the visual input. Such comparisons are modeled as a series of ratios and multiplications among near and far areas.

At the base of Retinex computation is the idea, presented above, of performing spatial comparisons among areas of the visual input (image) and computing a chain of ratio-product reset. The ratio-product reset mechanism is also the common core of the Milano-Retinex family, a variant developed at the Università degli Studi di Milano [5].

A view of the MI-Retinex family is visible in Fig. 3

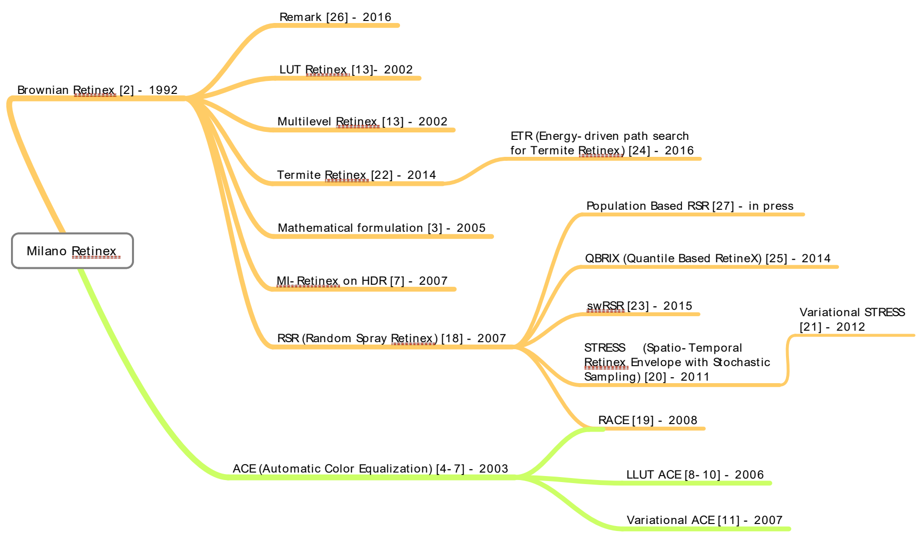

Fig. 3. The Milano Retinex family

Details about the works of Fig. 3, regarding the algorithms can be found in [6-27] and regarding some applications in [34-40].

3.3 Spatial and functional models of human retina

Retina characteristics and structure are often presented as well-known, however there are still several points to assess, like the total number of photoreceptors, the number of axons converging in the optical nerve and the size of the rod-free zone in the fovea. Retinal photoreceptor topography is also correlated to various perception phenomena, like the filling in taking place in the retinotopic region corresponding to the optic disk, and the differences in M to L cone ratio leading to no significant intersubjective differences in sensation, aspects that are still not fully explained.

Our research on the retina is focused on investigating the parameters that regulate the spatial distribution of photoreceptors in the human retina, and how the highly variable ratio of L to M cones between individuals affects our perception of color. To do this we are developing a model and its implementation of a human retina, to apply statistical models of photoreceptors distributions and create a functional model that will allow to simulate the photoreceptors' behavior in relation to the phototransduction of the visual signals and the elaboration of these signals in the retinal circuitry, to gain more insights on unclear aspects of how a light stimulus relates to the perception of color and to understand the nonlinear process of human vision. [3]

Human vision uses complex spatial processing to calculate appearance from retinal arrays. Hence, physiological limits of the human visual system are also to be considered, in particular veiling glare, defined as an uncontrolled spread of an image-dependent fraction of scene luminance in cameras and in the eye, is a strong component of our vision and one of the main issues of High Dynamic Range imaging. Retinal and post retinal spatial image processing increases apparent contrast, counteracting glare.

Research on the HVS also includes issues related to Color Vision Deficiency (CVD), also referred to as color blindness, and image processing techniques used to improve images for people with CVD, called Daltonization methods, consisting in a series of color correction algorithms that modify content in order to make it accessible for CVD observers. Details about our works on our HVS can be found in [41-49].

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