

Improvement of Contrast and Brightness in Consumer Video Using Video Processing Chain

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Abstract-The goal of this paper is to review the requirements of color and contrast processing in consumer video, and the key aspects of the processing as it relates to content, video algorithms involved, and display-specific processing. The perceptual objective of color and contrast enhancement is to increase vividness and colorfulness of all objects and detailed structures under different lightness conditions. That objective must be met for a variety of content formats and qualities which, in the age of DTV and HDTV have increased dramatically and put increasing pressure on the display processing engine performance.

Keywords- color enhancement, contrast enhancement, video processing.

I. INTRODUCTION

To review the requirements of color and contrast processing in consumer video we need an understanding of the processing objectives, e.g. color and contrast enhancement, the input source characteristics, e.g. format and content type, and the processing algorithms needed to match the display technology involved. Color and contrast enhancement in consumer video mainly focuses on improving the liveliness and fullness of color, enhancing details and visibility of the content of interest. Taking this one step further, all the enhancements have to be adaptive to variable lighting conditions in the image. Traditionally, color and contrast enhancements have been done using independent modules. Contrast adjustment is related to brightness and gamma settings, while color adjustment depends on lightness (perceptual dependency) and the color space used (chroma leak effect) [13, 12]. These independently interacting adjustments are not always tunable for optimum joint performance. Saturation is the key factor in increasing the colorfulness of an image. However, this feature of an image is tightly knit to its lightness. An increase in lightness often reduces the perceived saturation of an image, while a decrease in lightness often increases the perceived saturation. Hence, to achieve the best results in a video processing algorithm, a joint color, contrast and lightness enhancement is required to obtain visually appealing, high quality enhanced imagery. Proper overall processing of color along the video processing chain must deal with constraints such as chroma sub-sampling, compression artifacts, and color spaces used at the source, in the video algorithms, and in the display technology [2]. Since the final viewing experience is tied to the specific display modality, the enhancement algorithms may also

need to drive specific parameters of the display (e.g. color gamut, and backlight level/timing control in LCD). In this paper we start in Section 2 with a discussion of the main characteristics of the input content in terms of standard formats and color space, and then in Section 3 review the components of the video chain that affect color and contrast. In Section 4 we address the effects of display-specific processing methods that are designed to match the color/contrast characteristics of the display. Then, in Section 5 we provide a discussion of critical issues and areas of research for future work.

II. CONSUMER VIDEO CONTENT

DTV standards include 18 formats including 6 HDTV formats. Vertical resolution ranges from 480 to 1080 lines and includes interlaced formats. Horizontal resolution ranges from 640 to 1020 pixels. Frame rates vary from 24 to 120Hz (the color space used in the ITU standards is YCbCr). In the age of internet-connected DTV, processing subSD content (e.g. QCIF) by the video pipe is also required. To make it even more challenging, 240Hz DTV systems with SuperHD resolution have been demonstrated and are expected to hit the market in the coming years. DTV is also compatible with consumer equipment which can output content in RGB format, which is usually converted to YCbCr for processing. Accuracy of color space conversion is guaranteed by standard formulae, but it does not solve the problem of illegal colors

which can be generated during processing. Method such as simple clipping to keep values within the legal range can be applied, but may result in visual artifacts. Mathematically and perceptually sound methods such as gamut mapping are preferable to deal with color processing and conversion to avoid artifacts related to inconsistent processing methods [6]. Digital broadcast content comes in compressed format, which uses chroma sub-sampling. The most common formats are 4:2:0 and 4:2:2 (4:4:4 includes all samples). Moreover, the chroma samples are not always spatially collocated with the luma samples. To meet bandwidth constraints, compression ratios of 100:1 or more are commonly used in HDTV. If we assume that the final picture will be viewed at the maximum resolution on a large display (1080p, 52"TV). The logical expectation on quality is higher for the input formats with higher resolutions and lowest compression. Although it must deal with all use cases, even the best isplay processing engine will exhibit peak performance or only a certain input quality and format range.

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III. THE VIDEO PROCESSING CHAIN

The consumer video processing engine is typically made of a chain of modules that implement algorithms in three main categories. The categories are corrective processing, conditioning/formatting, and enhancement. Corrective processing takes care of reducing analog and digital (including compression) noise and artifacts. Conditioning includes scaling, deinterlacing, and scan rate conversion. Enhancement deals with color, contrast, sharpness, and resolution enhancement. The modules that deal specifically with color include chroma upconversion, i.e. conversion from 4:2:0 to 4:2:2 and 4:4:4 (see Figure 1).

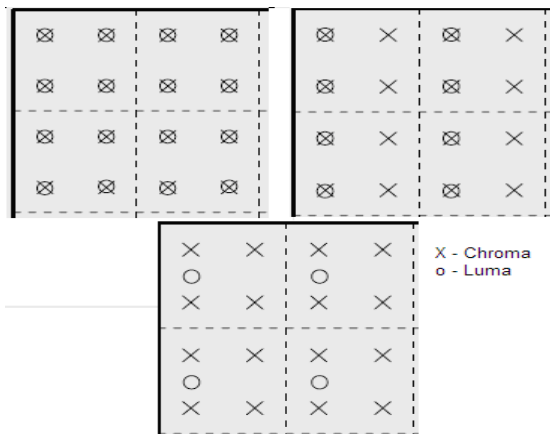


Figure 1. 4:4:4, 4:2:2 and 4:2:0 sampling patterns

Based on the theory of low information content in the color components (from the analog TV days), most processing was initially applied only to the luma component (while chroma, up-sampled to 4:2:2 was carried along); it was also used as a way to avoid the 3x increase in bandwidth required to process 3 full color components. As the quality race set off, color processing has become a more relevant subject. Noise reduction and compression artifact reduction in color components have become an active research area [1,3]. It has also become apparent that accurate removal of gamma correction is necessary for proper processing of the 3 components, e.g. R, G, and B. With the advent of high resolution formats, visibility and annoyance of color artifacts on large screen DTVS has called for more advanced algorithms not only for denoising and artifact reduction, but also for up-scaling. With the use of large scaling ratios, for example from subSD to HD, which can enlarge an image 3 to 5 times, other color artifacts related to scaling become apparent. Depending on the scaling method, artifacts such as blur, ringing, jaggies become apparent, and affect all components of the color space; plus scaling may amplify other errors stemming from improper color processing (e.g. edges may be mis aligned in the 3 components, causing color breakdown at sharp edges). The same is true for de-interlacing, where (depending on the approach) the main

If the input is in RGB, color space conversion to YCbCr is also used. Some modules such as skin tone enhancement may work on a different color space and thus require yet another color space conversion from and back to YCbCr. Advanced color and contrast enhancement modules such as the one proposed in [13], are placed towards the end of the video chain, and their performance depends on that of preceding modules starting from the chroma up conversion. Although it is a simple up-scaling applied to the sub sampling patterns shown in Figure 1, proper chroma up conversion depends on whether the video is interlaced or progressive, and in the case of interlaced whether the pixels are in motion or not. Improper 4:2:0

upconversion of interlaced content (i.e. applying a simple chroma up-scaling filter to the frames) results in a visual artifact known as the chroma bug



Figure 2. Chroma bug example

artifacts are flicker, jaggies and loss of resolution. Picture enhancement, particularly non-linear methods for sharpness enhancement and resolution enhancement (or up-scaling) have become compulsory features, making method such as Color Transient Improvement (CTI), statistical up conversion, and super-resolution well known topics in the consumer video industry [5,10,16]. The challenges of sharpness and resolution enhancement are easy to imagine, if we consider that the original input may be compressed, coded/decoded, and input in 4:2:0 SD format. Thus, we are witnessing the evolution of video processing from luma-only 2D processing to 2D+motion (motion adaptive and motion compensated), and to 3D processing of 3 components with increasing bit precision.

IV. DISPLAY-SPECIFIC PROCESSING

The transition from CRT to new display technologies including LCD, PDP, and DLP for the popular consumer segments has also brought about new display-specific or front-of-screen processing. LCD with its sample-and-hold and slow transition response characteristics (which cause artifacts not previously seen in CRT) has driven several innovations including 120Hz refresh rates, as well as backlight control to enhance global and local image contrast (and optimize power consumption) [8,9]—this work is also

related to the developments on HDR displays for consumer applications [15]. Motion compensated frame rate conversion from 24 to 120 fps has become a compulsory feature in today's LCD DTVs. Display gamut, support of deep color standard (HDMI 1.3, xvYCC[4]), require not only an output signal that is matched to the display input, but one that shows the visual advantage of features such as advanced lightness control (contrast), deep color (10/12/16 bits per color), and increased gamut (i.e., improved color rendition and colorfulness). Processing and quality evaluation that demonstrates the advantages of deeper color depends on display technology and proper content and viewing conditions. Starting with original content at 8bpc for example, is may the best way to show the advantages of a deep color display. As indicated before, color quality can be compromised from the early stages of processing. It is therefore critical to have the best possible signal (either from best possible source closely matched to the display characteristics, or after high quality video processing) to feed the display. Demonstrable enhancements afforded by display processing which match the display's resolution, gamut, response time, color depth, and contrast are the best way to showcase innovative technologies.

V. DISCUSSION

In spite of the advances in color processing achieved by the print and still imaging fields, consumer video processing has traditionally fallen behind. The advent of new display technologies and their technology-push effect has not only put increased pressure on the content providers and video capture equipment manufacturers to deliver improved visual quality, but on the video processing scientists and engineers to constantly deliver new methods that meet the challenges of matching state of the art display technology with processed content from a broad range of qualities and formats. We are thus facing the need for improved overall color.

Management in the framework of digital video processing. State of the art work on color and contrast enhancement and even on joint enhancement of lightness, color, and contrast can only result in limited gains in the large context of the consumer video experience. Previous attempts to design a video processing pipe have been aimed at increased color and tone reproduction, for instance by using RGB and CIELAB color space processing [7], do not solve the larger framework requirements of today's DTV systems. The range of visual quality distribution at the input of the video processing engine increases as we go from HD to SD, and to subSD input sources. In general, the capability of the video processing pipe is pushed to the limit by the smallest formats and the lowest quality (noisiest, most compressed) content. It is therefore imperative to define the region of performance in that space where video processing can afford the maximum improvement in visual quality, and design methods suited for that goal instead of using incremental improvements to the traditional architecture. We have discussed the main processing requirements related to source/format and display that must be met by the video processing engine. At the onset, if the color space used by

the video pipe is not matched to the color space depth and gamut of the input (e.g. latest digital HD video cameras), we are already losing information and quality that will not be easily recovered; especially if at the end we have a display compatible with latest color management standards. We indicated that although composed of many individual modules (e.g. denoising, scaling, color enhance, contrast enhance, sharpness enhance), to avoid complex interaction, the holistic approach to the video processing engine appears more promising than the multi-module cascade approach. Examples of this approach include joint processing for color/contrast enhancement [13], 3D processing instead of 2D+motion, and transformed space processing for multifunction processing [11,14]. Overall, we have pointed at present issues, as well as emerging ones stemming from the new trends in the field of consumer video. Color processing accuracy is only the first step. Future research is expected in the areas of multidimensional, multi-component processing, and objective color quality metrics that can be used in adaptive/intelligent processing. Further research on perception of color and color artifacts under variable motion conditions, perceptual adaptation (spatial and temporal), and the requirements of color processing for 3D video displays are also expected.

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