"Where is wisdom we have lost in knowledge? Where is the knowledge we have lost in information?" ~ T.S. Eliot (American born English Editor, Playwright, Poet and Critic, 1888-1965)

Chapter 7

CONCLUSIONS AND FUTURE RESEARCH

The comparative performance analysis and psychophysical experiments presented in this thesis demonstrate the challenges involved in designing an automatic color/contrast enhancement algorithm that will consistently produce pleasing results for various image/movie content. While conventional color and contrast enhancement methods in video processing typically involve signal and/or image processing, they do not generally consider the perceptual aspects of human vision. The novelty of the image enhancement approach developed as part of this research lies in the fact that it involves perceptual image processing and builds upon the knowledge acquired from past research in the field of color appearance. The new method combines color and contrast enhancement into one integrated algorithm, thereby producing optimal enhancement requiring no additional tune-up.

To summarize the research findings, following are some key aspects relevant for the development of an effective color and contrast enhancement method for images and video applications:

1. **The choice of color space is critical:** Image/video processing in a perceptually uniform color space helps in achieving visually pleasing results, while minimizing color artifacts and the need for additional color correction methods

2. **An ad hoc approach is detrimental:** It is preferable to achieve moderate enhancement for a wide variety of image content than superior enhancement in some cases and unacceptable results in others
3. **Color attributes are interdependent:** As lightness of a given color is increased, the corresponding maximum attainable saturation increases up to a certain value, then it decreases; the relationship is dependent on the hue
4. **Lightness adjustment should be globally adaptive:** An input image/video that is mostly dark should be lightened to an appropriate level, while an image/video with high lightness should be darkened
5. **Color enhancement should be content dependent:** Often times, a strong chroma enhancement can lead to a loss in detail, unrealistic colors, and in some cases, an out-of-gamut color (depending on the corresponding lightness and hue)
6. **Contrast enhancement should be locally adaptive:** A strong contrast enhancement may be objectionable in some cases (e.g. people's faces or uniform backgrounds), while in other cases it may help accentuate the details
7. **Certain colors may need special processing:** Memory colors like skin tone, natural green and blue sky may need special enhancement
8. **Noise should not be amplified:** If noise detection and suppression module does not precede color/contrast enhancement in a video processing chain, the algorithm must incorporate noise reduction filters

As the novel digital display technologies continue setting new standards for the quality of consumer video, the role of color processing becomes increasingly vital. Larger screen size, higher luminance and higher resolution of today's state-of-the-art digital display systems require significantly more sophisticated color imaging techniques than what was adequate a decade ago. Any future development efforts in color video processing must recognize the potential for improvement in color reproduction capabilities of various emerging display technologies. Using characterized video cameras with recorded camera settings at the capture end, video processing in a perceptually linear space, and displays with proper colorimetric characterization at the output end of the processing chain can all go a long way in ensuring consistent color reproduction across a myriad of display technologies. While this is easier said than done, video researchers and color scientists must work together toward the common goal of superior picture quality in consumer video applications.

At the same time, research on video quality assessment must go on in order to develop a reliable, universal perceptual video quality metric and an assessment methodology. This will be essential in benchmarking various video processing techniques, both display-specific and display-independent. Such an endeavor will require coordinated research efforts in the areas of human vision, color science and video processing.