

# Image Enhancement for the Visually Impaired: New Opportunities in the Digital Age

Matthew Fullerton<sup>+</sup>, Fuensanta Vera-Diaz<sup>\*</sup>, Russell L Woods<sup>\*</sup>, Eli Peli<sup>\*</sup>

<sup>\*</sup>The Schepens Eye Research Institute, Department of Ophthalmology, Harvard Medical School, Boston MA  
<sup>+</sup>Dept. of Electronics, University of York, UK



## ABSTRACT

Real-time, adjustable video contrast enhancement techniques for digital video have recently been developed and miniaturized. There are growing opportunities for the use of image enhancement to make television clearer for people with central vision impairment. By integrating an enhancement step into the standard digital TV or DVD decoder, adjustable image contrast enhancement can be achieved at little computational cost. Alternatively, the digital video output of any device can be processed with a simple and affordable device, small enough to work as an 'in-line' cable. The nature of the techniques are such that local image details are enhanced, often making important features in the video content clearer. We present an overview of these new technologies and results that demonstrate their favorable reception by those with and without visual impairment. We also demonstrate extensions to material for portable devices and internet broadcast.

## BACKGROUND

Decrease in contrast sensitivity (CS) at high spatial frequencies is common with low vision

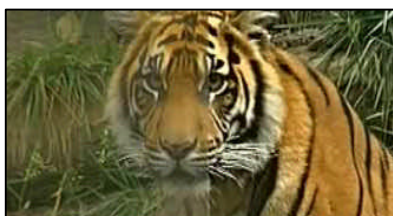
People with visual impairments (VI) watch TV more than they listen to radio

### How to make TV clearer?

- Get a larger TV, or sit closer to the TV
- Magnification, incl. Telescopes
- DVS: Descriptive Video Service



Image enhancement to compensate for CS losses was proposed by Peli et al. in 1986.



DigiVision<sup>®</sup> implementation of Peli & Lim Adaptive Enhancement algorithm in real time video (enhanced portion on the right)

## MPEG-2 Video for Digital TV & DVD Video Encoding

MPEG-2 video compression is integrated into DVD and HDTV

-Spatial blocks of image are transformed using a 2D DCT and so information is transformed to the spatial frequency domain.

-Transformed blocks are quantized using 8x8 matrices. This step discards high frequency information that is deemed unnoticeable.

Decoding in the TV set, DVD player etc. performs the reverse process, multiplying the data by the quantization matrix before the Inverse DCT operation is performed to transform back to spatially arranged information.

### MPEG-2 Enhancement

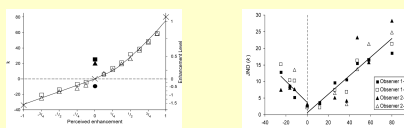
Multiplying DCT-block values by coefficients during the de-quantization step amplifies higher spatial frequencies in the image making them more visible to those with central vision impairment.



Examples of the MPEG-2 Enhancement from 'practice' video. Right side is enhanced

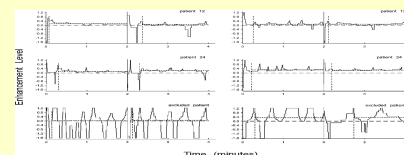
## Methods

Our PC-based system allows specification of which frequencies are increased and how much they are increased relative to others (filter) - integrated with media player so any MPEG-2 source can be enhanced.



Perceptual space examined by dividing enhancement space into equal perceptual increments and finding just noticeable diff (JND).

Single filter scaled up/down by remote control  
Tested 24 patients with VI and 6 normally sighted subjects.

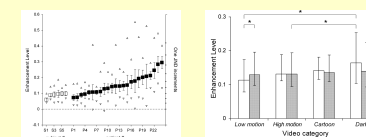


Responses of 3 patients with VI adjusting the level of enhancement while watching their first (left panel) and last video (right panel)

## Results

All participants, including normally sighted, chose to enhance the video.

Enhancement Level correlated with letter CS for 6.2° letters, 0.4° letters, and for the area under the CS function ( $p \leq 0.04$ ), and approached significance with 0.64° letters ( $p = 0.06$ ).



Average enhancement chosen by patients with VI (filled squares) & normally sighted subjects (open squares), open triangles show maximum & minimum level chosen. Error bars are 95% CI

Differences in the enhancement levels chosen by the patients with VI between some videos. Video in the white bar was always shown first. Error bars are IQR ( $^* = p < 0.05$ ).

Video demonstrations and software are available on our website <http://www.eri.harvard.edu/faculty/peli/>

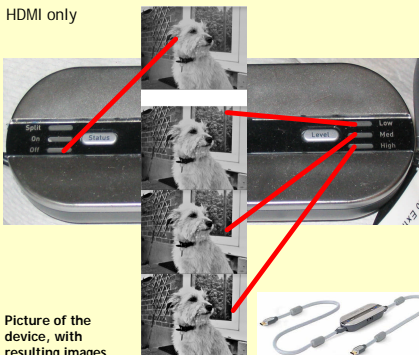
## Miniaturized DigiVision Enhancement

HDMI allows interconnection of devices (including computers) using only one cable to transmit digital video, audio and data.

Belkin have used DigiVision 'DV-1000' chip to provide small 'in-line' enhancement device

Marketed to high-end viewers (normally sighted)

HDMI only



Picture of the device, with resulting images

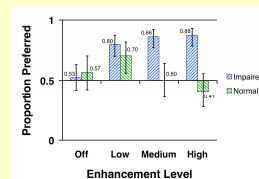
## Methods

Participants were asked 16 times which of 2 side-by-side TVs they preferred; one showed processed image, one shows unprocessed  
Loop of 6 movie videos was shown

## Results

Patients with VI preferred device at all levels.

Normally sighted subjects did not favour enhancement above "Low" setting and rejected "High" enhancement setting



Proportions of preference for the device at each level

## Conclusion

Normally sighted subjects may have rejected enhancement due to low quality source video, and close (3') seating distance

This device holds benefit for patients with VI and this or similar device could be useful and affordably distributed

Optimal settings not explored, and no ceiling was reached with patients, so further/more effective enhancement may be possible

## FUTURE PLANS

We are working with an electronic chip manufacturer to implement our MPEG decoding system in hardware. They hope to market an enhancing chip as a value-added feature to manufacturers of video decoders.

They have also applied our approach to newer MPEG4 & H.264 coded video. These newer video coders are used widely on the internet and for wireless delivery of video to mobile devices.



Comparison of H.264 video with and without enhancement

We are planning a study that will validate the benefit of the device with H.264 video, and demonstrate an improvement in perceived quality when the enhancement is applied.

### Acknowledgements

Supported in part by NIH grants EY05957 and EY12890.

None of the authors have any financial interest in the Belkin or DigiVision devices.