MPEG-Based Image Enhancement for the Visually Impaired: Implementation on a General-Purpose PC Platform

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ABSTRACT

A real-time contrast enhancement algorithm for MPEG was implemented, demonstrating that the concepts proposed by Kim & Peli (SID 2003) are computationally efficient enough to run on a general purpose PC. The application supports further research into the effectiveness of the technique for those with visual impairments.

BACKGROUND

Image Enhancement

- Decreases in contrast sensitivity at high spatial frequencies are common in people with low vision.

- Image enhancement to compensate for these losses was first proposed by Peli & Peli[1] in 1984.

DigiVision ® implementation of Peli & Peli algorithm (enhanced portion on the right)

MPEG-2 Video Encoding

- Developed for "Generic coding of moving pictures".

- Compresses video to bandwidths for DVD/broadcast.

- Pictures divided into luminance and chrominance *blocks*.

- Best matches between successive blocks are found; *differences* and *motion vectors* computed.

- Spatial blocks (intra) and difference blocks (inter) are transformed using a 2D DCT.

- Transformed blocks are *quantized* using 8x8 matrices.

- This results in many zeroes; allows run-length & Huffman coding, reducing bit stream size.

8	16	19	22	26	27	29	34
16	16	22	24	27	29	34	37
19	22	26	27	29	34	34	38
22	22	26	27	29	34	37	40
22	26	27	29	32	35	40	48
26	27	29	32	35	40	48	58
26	27	29	34	38	46	56	69
27	29	35	38	46	56	69	83

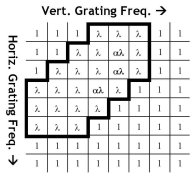
Intra-block Q-matrix

- Decoding performs the reverse process, multiplying the data by the quantization matrix before the inverse DCT operation is performed. Pictures are reassembled.

MPEG-2 Enhancement

- The diagonals of values in the DCT-domain are arranged in increasing spatial frequency.

- By multiplying some of these values by a coefficient during de-quantization, we can amplify spatial frequencies not visible to those with low vision.



Pointwise multiplier filter used previously[2]

- The technique has been implemented previously[2] by processing MPEG-2 files to modify the quantization matrices.

- It was argued[2] that it would be simple to implement the technique in real time.

IMPLEMENTATON

Decoder programming

- *libmpeg2* is an open-source software library to decode MPEG-2 streams, written in C.

- Dequantization functions were modified to implement the algorithm, at the **block** level.

- We have registered our MPEG decoder with the MPEG licensing authority.

Decoder Control

- We created an interface to alter all of the parameters affecting our decoder, as shown below.

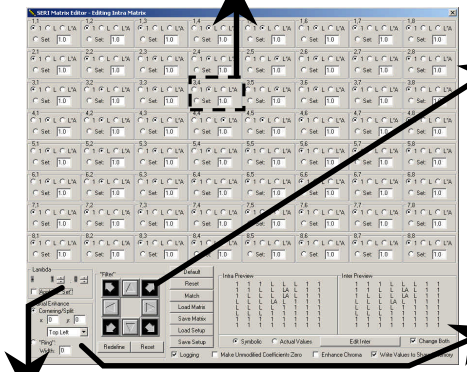
- The interface can be used as a simple real-time control for the implementation of the previous method, a matrix-level research interface, or a mixture of both.

Individual Coefficient Control

Use preset coefficients

Do not enhance

Set manually, for direct effect, or for scaling purposes (see Scaling, below)



Scaling

- An up/down control allows us to adjust the enhancement for either,

the original filter:

multiple coefficients = ?, some = ?.a,

or new custom filters:

each coefficient = (manually set value x ?) +1.

- These controls can also be adjusted using the remote control handset.

Filter Shifts

- We required the ability to move the entire set of coefficients along the upper-left to lower-right diagonal axis of increasing spatial frequency.

- An 8x8 'filter' can be completely moved off the used 'grid' without losing the contents of the filter.

- If a new preferred position is found, the button 'Redefine' can be used to set the currently used 8x8 as that for further shifts.

Partial Enhancement

- *Adaptation*, whereby the viewer's vision becomes adapted to an enhancement and perceives it as the normal level[3] might prevent subjects from appreciating enhanced images.

- The interface can set parameters such that a corner, half (right) or 'ring' will be unenhanced.

- The effect of the enhancement is now always apparent to the viewer.

Partial Screen Enhancement

Media Player Integration

- The libmpeg2 decoder has already been integrated into more complete software "media players", an example being the "VideoLAN Client" (VLC).

- We recompiled VLC with the modified decoder.

- This allows raw MPEG-2 ES streams extracted from higher level media such as DVDs to be passed to the library for decoding, enhancing this material..

VideoLAN Client (VLC)

IMPACT

Our implementation, within the decoder, improved functionality compared to the previous[2] method;

- Alteration of values in real time

- Enhancement of luminance components only

- Enhancement of portions of the picture only

The real-time nature of the system allowed us to solve two large long term problems with **edges** and **motion**.

Edge Ringing

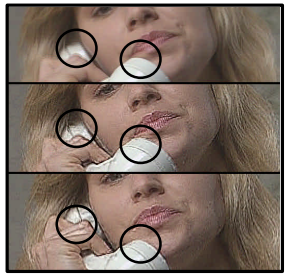
- The flexible interface has facilitated the development of better filters.

- The previous enhancement exhibited ringing artifacts at sharp edges. Our newer filters have significantly reduced these artifacts.

(a) Example of new filter (b) Previous (?=7) filter The edge ringing was especially noticeable on text.

Motion Artifacts

We have reduced motion artifacts by deinterlacing using an appropriate filter (below) or a television screen.



(a) Interlacing artifacts present in video
(b) These are highlighted by enhancement
(c) Deinterlacing the video reduces these
(The effect is especially noticeable within the circled regions)

FUTURE PLANS

We are studying patient impressions of the enhancement. Patients will be given the opportunity to adjust the enhancement level in real time using a remote control as a selection of videos are played.

System in Testing

Acknowledgements

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References

[1] E. Peli and T. Peli, "Image enhancement for the visually impaired," Optical Engineering 23/1, 47-51 (1984).

[2] J. Kim, A. Vora and E. Peli, "MPEG-based image enhancement for the visually impaired," Optical Engineering, 43/6, 1318-1328 (2004).

[3] M. A. Webster, M. A. Georgeson and S.M. Webster, "Neural adjustments to image blur," Nature Neuroscience, 5/9, 839-840 (2002).