



Advanced Applications: Improving Image and Video Compression

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Outline of Talk

- *Introduction*
- *DCTune*
- *Future Image Compression*
 - *Wavelets*
 - *Edge Based Coding*
- *Conclusions*



DVEC Advanced Applications

- *Research and Evaluate Future Desktop Video and Networked Video Technologies.*
- *Develop New Technologies as Appropriate*
- *Software and Algorithm Development*
- *http://zeus.arc.nasa.gov/adv_apps.html*



DVEC Advanced Applications

- *Implementing complex multimedia algorithms in C and C++.*
- *Porting complex multimedia algorithms in C/C++ to different processors including PC, Unix, and Macintosh.*
- *Expertise in signal and image processing.*
- *Familiarity with Microsoft Windows*



Who am I?

- *Developed commercial MPEG-1 and MPEG-2 audio and video playback (decoder) software written in C for PC/Windows, Power Macintosh, and Unix platforms.*
- *Further work in image and video compression for NASA. More later.*



Who am I?

- *Image, Video, and Audio Compression Algorithms*
- *Ph.D. in Physics, University of Illinois at Urbana-Champaign*
 - *Maximum Likelihood Fitting Methods*
 - *Monte Carlo Simulations*
 - *Pattern Recognition*



Introduction

- *Digital video and still images place very high demands on network bandwidth and memory storage.*
- *Improved video and image compression complements higher bandwidth networks and higher capacity storage media.*



Introduction

- *Very high compression of images and video requires lossy compression in which information is removed from the image by the compression process.*
- ***Theme:*** *remove information that the human viewer cannot perceive or treats as unimportant.*



Introduction

- *MPEG-1/2/4, H.263, H.261, DV, and JPEG are all based on Block Discrete Cosine Transform (DCT).*
- *Block DCT works because the human visual system is less sensitive to higher spatial frequency components in surface textures in images.*



Introduction

- *Improved video and image compression must remove information that human viewers do not perceive or consider unimportant. (e.g. high spatial frequency details in surface textures)*
- *Improved video and image compression must preserve information that human viewers perceive or, at least, consider important. (e.g. sharp edges)*



Some Current Projects

- *DCTune: Perceptual Optimization of JPEG Images (with Ames Vision Science and Technology Group)*
- *Studies of Wavelet, Fractal, and Other Leading Edge Video Coding Technologies*
 - *Smooth full-motion video over Internet?*
 - *Smooth full-motion video over telephone?*



DCTune

- *DCTune is a technology for optimizing JPEG still image compression. DCTune calculates the best JPEG quantization matrices to achieve the maximum possible compression for a specified perceptual error, given a particular image and a particular set of viewing conditions.*



DCTune



Original "Flag" Image (Before Block DCT)



DCTune



Block DCT of the "Flag" Image



DCTune

- *Block DCT divides image into 8 x 8 pixel blocks.*
- *Small flag sub-image in upper left corner is the (0,0) DCT coefficient, simply the average of all 64 pixels in each 8x8 block.*
- *Other sub-images are the (0,1) ... (8,8) DCT coefficients.*



DCTune

- *Most of the “Flag” image ends up in upper left corner, the low frequency DCT coefficients.*
- *Human viewers have reduced sensitivity to the high frequency components.*
- *MPEG, H.263, H.261, and JPEG are all based on this happy coincidence.*



DCTune

- *JPEG divides each DCT coefficient by a quantization factor. MPEG digital video works the same way!*
- *DCTune can predict visibility of artifacts introduced by this division by quantization factor.*
- *DCTune determines correct quantization factor for desired perceptual error.*



DCTune

- *Patented NASA algorithm developed by Andrew B. Watson, Al Ahumada, and others with the Vision Science and Technology Group.*
- *Mathematica Prototype*
- *Converted to compiled C language binary executable*
- *<http://vision.arc.nasa.gov/dctune2.0.html>*



DCTune Benefits

- *Accurate specification of visual quality. DCTune incorporates a scale that relates directly to perceptual quality. A value of 1 indicates perceptually lossless quality.*
- *Custom quantization matrices optimized for specific applications (printing, web, web-tv, medical imaging, tv, video, dv, digital tv, hdtv, etc).*



DCTune Benefits

- *Reduced file size. For a given level of visual quality, DCTune will produce a smaller file than standard JPEG.*
- *Accurate measurement of perceptual error in processed images (not just JPEG images).*



DCTune

- *DCTune 2.0 completed and available.*
- *Advanced Applications is working with Ames Vision Science and Technology Group on a digital video extension of DCTune for Motion-JPEG, MPEG, and other digital video formats.*



Future Image Compression

- *Block Discrete Cosine Transform limited by:*
 - *Blocking Artifacts*
 - *Blurring and Ringing at Edges*
- *Wavelet Image and Video Coding*
- *Edge-based Image and Video Coding*



Limits of the Block DCT



JPEG Encoder in Paint Shop Pro



Future Image Compression

- *Wavelet Image and Video Coding*
- *Works for similar reasons to Block DCT*
- *Does not divide image into blocks.*
- *Several working products exist.*
- *Well past the working prototype stage.*
- *Not standardized. MPEG-4 and JPEG-2000 standards may incorporate.*



Future Image Compression

- *Wavelets Outperform the Block DCT*
 - *Intel Indeo 5.0*
 - *VDO Net's VDOWave/VDOLive*
- *Wavelet Image and Video Coding limited by:*
 - *Blurring and Ringing at Edges*
- *Example of wavelet blurring follows:*



Edges and Wavelets



Wavelet Image Construction Kit (Geoff Davis)

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Future Image Compression

- *Edge-based Image and Video Coding*
- *Human viewers are highly sensitive to sharp edges and lines in images.*
- *Sharp edges and lines correspond to physical objects that humans must identify and track **accurately** to survive.*
- *Future methods must preserve sharp edges at very high compression ratios.*



Future Image Compression

- *Edge-based Image and Video Coding*
- *Possibly based on edge-detection algorithms such as:*
 - *Marr-Hildreth*
 - *Canny*
 - *Shen-Castan*
- *Current edge-detection algorithms are probably not good enough. :-)*



Conclusions

- *Block DCT Rules*
- *Wavelet image and video compression is technically superior to Block DCT.*
- *Wavelet image and video may replace Block DCT in near future.*
- *Edge-based image and video coding in the intermediate to distant future.*



Where to Get This Talk

- *<http://zeus.arc.nasa.gov/cee.pdf>*
 - *Adobe PDF Format Version*
- *<http://zeus.arc.nasa.gov/cee.ppt>*
 - *Microsoft **Windows** Power Point Version*
- *<http://zeus.arc.nasa.gov/>*
 - *Desktop Video Expert Center Web Site*