Dpcm – college essay

DPCM – Overview Principle of Differential Pulse Code Modulation (DPCM) Characteristics of DPCM quantization errors Predictive coding gain Adaptive intra-interframe DPCM Conditional Replenishment Bernd Girod: EE398B: Image Communication II DPCM no. 1 Principle of DPCM input s + e quantizer + s predictor + s’ e’ entropy coder channel coder output s’ + predictor s + e’ entropy decoder channel decoder Prediction error Reconstruction Reconstruction error = quantization error e= s? s ? s ? = e? + s ? s? ? s = e? ? e = q DPCM no. 2 Bernd Girod: EE398B: Image Communication II Quantization error feedback in the DPCM coder

Assuming a linear predictor, the DPCM coder is equivalent to the following structure: ~ s + e e quantizer e’ predictor s (s) s (q) predictor q (e) + Transfer function of the prefilter: ? E (?) = [1 ? P(?)]S(?) ? – abbreviation for frequency vector, ? e. g. , (x , ? y) transfer function of the predictor Transfer function of quantization error feedback: ? E ? (?) = E(?) + [1 ? P(?)]Q(?) Bernd Girod: EE398B: Image Communication II DPCM no. 3 Power spectrum of the DPCM quantization error Power spectral density of the quantization error q measured for intraframe DPCM with a 16 level quantizer ? ?? 0 0 ? x ? y ? ??

Bernd Girod: EE398B: Image Communication II DPCM no. 4 Signal distortions due to intraframe DPCM coding Granular noise: random noise in flat areas of the picture Edge busyness: jittery appearance of edges (for video) Slope overload: blur of high-contrast edges, Moire patterns in periodic structures. Bernd Girod: EE398B: Image Communication II DPCM no. 5 Example of intraframe DPCM coding 1 bit/pixel prediction error coding slope overload 2 bit/pixel edge busyness granular noise 3 bit/pixel Linear predictor: 0 1/2 1/4

1/4 4 bit/pixel original Lloyd-Max quantizers Fixed-length coding DPCM no. 6 Bernd Girod: EE398B: Image Communication II

Recall from EE398A: High-rate performance of scalar quantizers High-rate distortion-rate function d (R) ? ? ? 2 2 2 X Scaling factor ? 2 ? 2 R Shannon LowBd Uniform Laplacian Gaussian 6 ? 0. 703 ? e e ? 0. 865 Lloyd-Max 1 9 = 4. 5 2 3? ? 2. 721 2 Entropy-coded 1 e2 ? 1. 232 6 ? e ? 1. 423 6 DPCM no. 7 ? 1 Bernd Girod: EE398B: Image Communication II Predictive coding gain Distortion-rate function with DPCM d DPCM (R) ? ? e2? e2 2? 2 R Prediction gain Variance of prediction error GDPCM ? s2? s2 = 2 2 ? e? e Smallest achievable prediction error variance for N-dimensional signal determined by spectral flatness ? 1 ? ? e2 = exp ? n (? xx (?)) d ? ? N ? ? (2?) ? ? ? ? Bernd Girod: EE398B: Image Communication II DPCM no. 8 Predictive coding gain (cont.) Consider 1-D Gaussian Markov-1 process with correlation coefficient ? k 2 Autocorrelation function E [S n S n ? k] = ? s ? Prediction gain GDPCM 1 = 1? ? 2 Bernd Girod: EE398B: Image Communication II DPCM no. 9 R-D curves for Gauss-Markov-1 source SNR [dB] = 10log10 ? 2 D 35 30 25 20 15 10 5 0 0 1 2 3 • Linear predictor order N= 1, a= 0. 9 • Entropy-Constrained Scalar Quantizer with Huffman VLC • Iterative design algorithm applied R(D*), ? = 0. 9 DPCM & ECSQ Panter & Dite App Entropy-Constrained Opt. 5 6 DPCM no. 10 7 R [bits] Bernd Girod: EE398B: Image Communication II Prediction example: test pattern original 0 0. 95 0 0 0 0 0. 95 0 0 0. 5 0. 5 0 Bernd Girod: EE398B: Image Communication II DPCM no. 11 Prediction example: Cameraman original 0 0. 95 0 0 0 0 0. 95 0 0 0. 5 0. 5 0 Bernd Girod: EE398B: Image Communication II DPCM no. 12 Histograms: Cameraman Image signal 3000 2500 2000 1500 1000 500 0 0 50 100 150

200 250 0. 5 0 x 10 2 1. 5 1 4 Prediction error 0 0. 5 0. 5 0 -50 0 50 Bernd Girod: EE398B: Image Communication II DPCM no. 13 DPCM with entropy-constrained quantization K= 511, H= 4. 79 bpp K= 15, H= 1. 98 bpp K= 3, H= 0. 8 bpp K… number of reconstruction levels, H… entropy [J. R. Ohm] Bernd Girod: EE398B: Image Communication II DPCM no. 14 Transmission errors in a DPCM system • For a linear DPCM decoder, the transmission error response is superimposed to the reconstructed signal S' • For a stable DPCM decoder, the transmission error response decays • For variable length coding, loss of synchronization can lead to errors in many prediction error samples after a single bit-error Bernd Girod: EE398B: Image Communication II DPCM no. 15 Transmission errors in a DPCM system (cont.) Example: Error rate: Lena, 3 bpp (fixed code word length) p= 10-3 0 0. 5 0 0 0 0 0. 95 0 0 0. 5 0. 5 0 [J. R. Ohm] Bernd Girod: EE398B: Image Communication II DPCM no. 16 Interframe coding of video signals Interframe coding exploits similarity of temporally successive pictures Important interframe coding methods: Adaptive intra-interframe coding Conditional replenishment Motion-compensated prediction Bernd Girod: EE398B: Image Communication II DPCM no. 17 " It has been customary in the past to transmit successive complete images of the transmitted picture. " […] " In accordance with this invention, this difficulty is avoided by transmitting only the difference between successive images of the object. Bernd Girod: EE398B: Image Communication II DPCM no. 18 Principle of adaptive intra-interframe DPCM Predictor is switched between two states: A: Intraframe prediction for moving or changed areas. B: Interframe prediction (previous frame prediction) for still areas of the picture. frame s m interval ? 40 S22 S 23 S24 S2 S3 S4 S 22 S23 S24 S2 S3 S4 S 21 S20 S25 FRAME N – 1 S21 S 20 S25 S1 S0 FRAME N

FRAME N – 1 S1 S0 FRAME N ? Sintra = a1 S1 + a 2 S2 + a3 S3 + a 4 S4 Bernd Girod: EE398B: Image Communication II ? Sinter = S20 DPCM no. 19 Intra-interframe DPCM: feedback adaptation s + ^ s ^ sinter

Interframe predictor Intraframe predictor Predictor adaptation e Quantizer e' Entropy coder e' Entropy decoder s' ^ s ^ sinter Interframe predictor Intraframe predictor Predictor adaptation s' ^ sintra ^ sintra Coder Decoder Bernd Girod: EE398B: Image Communication II DPCM no. 20 Intra-interframe DPCM: feedforward adaptation s + ^ s ^ sinter Interframe predictor Intraframe predictor e Quantizer e' e' Entropy coder Entropy decoder s' ^ s ^ sinter Interframe predictor Intraframe predictor s' ^ s ^ s intra intra Predictor adaptation intra-/interframe switching information Coder Bernd Girod: EE398B: Image Communication II

Decoder DPCM no. 21 Conditional replenishment SIGNAL INPUT CODING, ADDRESSING, BUFFERING SEGMENTER Change (MOVEMENT detector DETECTOR) TRANSMISSION CHANNEL BUFFERING, DECODING, ADDRESSING SIGNAL OUTPUT FRAME Frame DELAY store Frame store CODER DECODER Still areas: repeat from frame store Moving areas: encode and transmit address and waveform Bernd Girod: EE398B: Image Communication II DPCM no. 22 Change detection Example of a pixel-wise change detector Current frame + ABS Previous frame Average of 3×3 window Threshold Eliminate isolated points or pairs of points Decision changed/ unchanged

Example of a block-wise change detector Current frame + ABS Previous frame Bernd Girod: EE398B: Image Communication II DPCM no. 23 Accumulate over NxN blocks Threshold Decision changed/ unchanged Rate-distortion optimized mode selection How to choose the decision threshold, if distortion D shall be minimized for a given rate R? Assumptions Blockwise mode selection, block index i Lagrangian cost function i Additive overall distortion D = ? Di and rate R = ? Ri i i J = D + ? R = ? Di + ? Ri = ? J i i Strategy: minimize Ji for each block i separately, using a common Lagrange multiplier ?

Bernd Girod: EE398B: Image Communication II DPCM no. 24 Rate-distortion optimized mode selection (cont.) Consider 2 blocks with D(R) = D1(R1) +D2(R2) D D1(R1) D2(R2) R Bernd Girod: EE398B: Image Communication II DPCM no. 25 The “ Dirty Window” effect Conditional replenishment scheme with change detection threshold set too high leads to the subjective impression of looking through a dirty window. Background Moving area picked up by change detector Moving areas missed by change detector Bernd Girod: EE398B: Image Communication II DPCM no. 26 Crawford noise reduction filter f(?) + noisy video signal ? – NonNL linearity (?) + ? + frame store clean video signal Bernd Girod: EE398B: Image Communication II DPCM no. 27 DPCM – Summary DPCM: Prediction from previously coded/transmitted samples (known at transmitter and receiver) Typical signal distortions for intraframe DPCM: granular noise, edge busyness, slope overload Prediction gain depends on spectral flatness Adaptive Intra-Interframe-DPCM: forward adaptation vs. backward adaptation Conditional replenishment: only transmit frame-to-frame changes Temporal noise reduction by nonlinear, recursive frame differencing Bernd Girod: EE398B: Image Communication II DPCM no. 28