Near-Capacity Variable Length Coding

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Contents

List of Symbols

Schematics

$\mathbf{f}_n$ Current video frame.
$\hat{\mathbf{f}}_n$ Quantised current video frame.
$\tilde{\mathbf{f}}_n$ Reconstructed current video frame.
$\hat{\mathbf{f}}_{n-1}$ Quantised previous video frame.
$\tilde{\mathbf{f}}_{n-1}$ Reconstructed previous video frame.
$\mathbf{e}$ Source sample frame.
$\hat{\mathbf{e}}$ Quantised source sample frame.
$\tilde{\mathbf{e}}$ Reconstructed source sample frame.
$\mathbf{s}$ Source symbol frame.
$\tilde{\mathbf{s}}$ Reconstructed source symbol frame.
$\mathbf{u}$ Transmission frame.
$\hat{\mathbf{u}}$ Received transmission frame.
$\tilde{\mathbf{u}}$ Reconstructed transmission frame.
π Interleaving.
π^{-1} De-interleaving.
$\mathbf{u}'$ Interleaved transmission frame.
$\mathbf{v}$ Encoded frame.
$\mathbf{v}'$ Interleaved encoded frame.
$L_a(\cdot)$ *A priori* Logarithmic Likelihood Ratios (LLRs)/logarithmic *A Posteriori* Probabilities (Log-APPs) pertaining to the specified bits/symbols.
$L_p(\cdot)$ *A posteriori* LLRs/Log-APPs pertaining to the specified bits/symbols.
$L_e(\cdot)$ Extrinsic LLRs pertaining to the specified bits/symbols.
$\mathbf{x}$ Channel's input symbols.
$\mathbf{y}$ Channel's output symbols.

Channel

η Effective throughput.
E_c/N_0 Channel Signal to Noise Ratio (SNR).
E_b/N_0 Channel SNR per bit of source information.

Video blocks (VBs)

J_x^{MB} Number of VB columns in each Macro-Block (MB).
J_y^{MB} Number of VB rows in each MB.
J^{MB} Number of VBs in each MB.

Sub-frames

M Number of sub-frames.
m Sub-frame index.
$\mathbf{e}^m$ Source sample sub-frame.
$\hat{\mathbf{e}}^m$ Quantised source sample sub-frame.
$\tilde{\mathbf{e}}^m$ Reconstructed source sample sub-frame.
$\mathbf{u}^m$ Transmission sub-frame.
$\tilde{\mathbf{u}}^m$ Reconstructed transmission sub-frame.
$\mathbf{s}^m$ Source symbol sub-frame.
$\tilde{\mathbf{s}}^m$ Reconstructed source symbol sub-frame.

Source sample sub-frames

J Number of source samples that are comprised by each source sample sub-frame.
J^{sum} Number of source samples that are comprised by each source sample frame.
j Source sample index.
e_j^m Source sample.
$\hat{e}_j^m$ Quantised source sample.
$\tilde{e}_j^m$ Reconstructed source sample.

Transmission sub-frames

I Number of bits that are comprised by each transmission sub-frame.
I^{sum} Number of bits that are comprised by each transmission frame.
I_{min} Minimum number of bits that may be comprised by each transmission sub-frame.
I_{max} Maximum number of bits that may be comprised by each transmission sub-frame.
i Transmission sub-frame bit index.
u_i^m Transmission sub-frame bit.
b Binary value.

Codebooks

K Number of entries in the codebook.
k Codebook entry index.

VQ codebook

$\mathbf{VQ}$ Vector Quantisation (VQ) codebook.
$\mathbf{VQ}^k$ VQ tile.
J^k Number of VBs that are comprised by the VQ tile $\mathbf{VQ}^k$.
j^k VQ tile VB index.
$VQ_{j^k}^k$ VQ tile VB.

VLC codebook

$\mathbf{VLC}$ Variable Length Coding (VLC) codebook.
$\mathbf{VLC}^k$ VLC codeword.
I^k Number of bits that are comprised by the VLC codeword $\mathbf{VLC}^k$.
I_b^k Number of bits in the VLC codeword $\mathbf{VLC}^k$ assuming a value $b \in \{0, 1\}$.
i^k VLC codeword bit index.
$VLC_{i^k}^k$ VLC codeword bit.

VLC codebook parameters

E Entropy.
$L(\mathbf{VLC})$ VLC codebook average codeword length.
$R(\mathbf{VLC})$ VLC coding rate.
$E(\mathbf{VLC})$ VLC-encoded bit entropy.
$T(\mathbf{VLC})$ VLC trellis complexity.
$O^{\mathrm{APP}}(\mathbf{VLC})$ Average number of Add, Compare and Select (ACS) operations performed per source symbol during *A Posteriori* Probability (APP) Soft-In Soft-Out (SISO) VLC decoding.
$O^{\mathrm{MAP}}(\mathbf{VLC})$ Average number of Add, Compare and Select (ACS) operations performed per source symbol during Maximum *A posteriori* Probability (MAP) VLC sequence estimation.
$d_{\mathrm{free}}(\mathbf{VLC})$ VLC codebook free distance.
$d_{b_{\min}}(\mathbf{VLC})$ VLC codebook minimum block distance.
$d_{d_{\min}}(\mathbf{VLC})$ VLC codebook minimum divergence distance.
$d_{c_{\min}}(\mathbf{VLC})$ VLC codebook minimum convergence distance.
$\bar{d}_{\mathrm{free}}(\mathbf{VLC})$ VLC codebook free distance lower bound.
$D(\mathbf{VLC})$ VLC codebook Real-Valued Free Distance Metric (RV-FDM)

Irregular Variable Length Coding (IrVLC)

N Component VLC codebook count.
n Component VLC codebook index.
$\mathbf{u}^n$ Transmission sub-frame.
$\mathbf{s}^n$ Source symbol sub-frame.
C^n Component VLC codebook source symbol frame fraction.
α^n Component VLC codebook transmission frame fraction.

IrVLC codebooks

$\mathbf{VLC}^n$ Component VLC codebook.
$\mathbf{VLC}^{n,k}$ Component VLC codeword.
$I^{n,k}$ Number of bits that are comprised by the component VLC codeword $\mathbf{VLC}^{n,k}$.
$i^{n,k}$ Component VLC codeword bit index.
$VLC_{i^{n,k}}^k$ Component VLC codeword bit.

Irregular Unity Rate Coding (IrURC)

R Component Unity Rate Code (URC) count.
r Component URC index.
$\mathbf{u'}^r$ Interleaved transmission sub-frame.
$\mathbf{v}^r$ Encoded sub-frame.
$\mathbf{URC}^r$ Component URC.

Code parameters

$R_{(\cdot)}$ Coding rate.
$M_{(\cdot)}$ Number of modulation constellation points.
$L_{(\cdot)}$ Coding memory.

EXtrinsic Information Transfer (EXIT) chart

I_a *A priori* mutual information.
I_e Extrinsic mutual information.
y Importance of seeking a reduced computational complexity during EXIT chart matching.

Trellises

$\ddot{\imath}$ Bit state index.
$\ddot{\jmath}$ Symbol state index.
$\ddot{n}$ Node state index.
$S_{(\ddot{\imath},\ddot{\jmath})}$ Symbol-based trellis state.
$S_{(\ddot{\imath},\ddot{n})}$ Bit-based trellis state.

Trellis transitions

T Trellis transition.
k^T Codebook entry index associated with the symbol-based trellis transition T.
b^T Bit value represented by the bit-based trellis transition T.
$\imath^T$ Index of bit considered by the bit-based trellis transition T.
$\ddot{\imath}^T$ Bit state index of the trellis state that the symbol-based trellis transition T emerges from.
$\ddot{\jmath}^T$ Symbol state index of the trellis state that the symbol-based trellis transition T emerges from.
$\ddot{n}^T$ Node state index of the trellis state that the bit-based trellis transition T emerges from.

Trellis sets

$\mathrm{en}(u_i^m)$ The set of all trellis transitions that encompasses the transmission sub-frame bit u_i^m.
$\mathrm{en}(u_i^m = b)$ The sub-set of $\mathrm{en}(u_i^m)$ that maps the binary value b to the transmission sub-frame bit u_i^m.
$\mathrm{en}(\hat{e}_j^m)$ The set of all trellis transitions that encompasses the VB $\hat{e}_j^m$.
$\mathrm{en}(\hat{e}_j^m = VQ_{j^k}^k)$ The sub-set of $\mathrm{en}(\hat{e}_j^m)$ that maps the VQ tile $VQ_{j^k}^k$ to the VB $\hat{e}_j^m$.

$\mathrm{fr}(S)$ The set of all transitions that emerge from the trellis state S.
$\mathrm{to}(S)$ The set of all transitions that merge to the trellis state S.
$\mathrm{fr}(T)$ The state that the transition T emerges from.
$\mathrm{to}(T)$ The state that the transition T merges to.
$\mathrm{nr}(\hat{e}_j^m)$ The set of all VBs that immediately surround the VB $\hat{e}_j^m$.

Viterbi algorithm

$d(T)$ The distortion of the trellis transition T.
$D(T)$ The minimum cumulative distortion of all trellis paths between the trellis state $S_{(0,0)}$ and the trellis transition T.
$D(S)$ The minimum cumulative distortion of all trellis paths to the state S.
$m(T)$ The Viterbi algorithm metric of the trellis transition T.
$M(T)$ The maximum cumulative Viterbi algorithm metric of all trellis paths between the trellis state $S_{(0,0)}$ and the trellis transition T.
$M(S)$ The maximum cumulative Viterbi algorithm metric of all trellis paths to the state S.
$M(S)$ The maximum cumulative Viterbi algorithm metric of all trellis paths to the sate S.

Bahl-Cocke-Jelinek-Raviv (BCJR) algorithm

$P_a(u_i^m = b)$ *A priori* probability of the transmission sub-frame bit u_i^m taking the value b.
$P(k)$ Probability of occurrence of the codebook entry with index k.
$P(S)$ Probability of occurrence of the trellis state S.
$P(T|\mathrm{fr}(T))$ Conditional probability of the occurrence of the trellis transition T given the occurrence of the trellis state that it emerges from.
$P_p(T)$ *A posteriori* trellis transition probability.
C_1 *A posteriori* trellis transition probability normalisation factor.
$\gamma(T)$ *A priori* trellis transition probability.
$\gamma'(T)$ Weighted *a priori* trellis transition probability.
$C_2(S)$ *A priori* trellis transition probability normalisation factor used for all trellis transitions that emerge from the trellis state S.
$\alpha(S)$ Alpha value obtained for the trellis state S.
$\beta(S)$ Beta value obtained for the trellis state S.
C_{L_a} BCJR algorithm LLR pruning threshold.
C_γ BCJR algorithm *a priori* probability pruning threshold.
C_α BCJR algorithm forward recursion pruning threshold.
C_β BCJR algorithm backwards recursion pruning threshold.

Genetic Algorithm (GA) for VLC codebook design

$\mathbf{L}$ List of candidate VLC codebooks.
L^{tar} Target GA list length.
$M(\mathbf{VLC})$ GA VLC quality metric.
D^{lim} GA VLC RV-FDM limit.
R^{lim} GA VLC coding rate limit.

α^D GA VLC RV-FDM importance.
α^R GA VLC coding rate importance.
α^E GA VLC bit entropy importance.
α^T GA VLC trellis complexity importance.
β^D GA VLC RV-FDM increase/decrease constant.
β^R GA VLC coding rate increase/decrease constant.
D^{best} Most desirable RV-FDM of VLC codebooks admitted to the GA list.
R^{best} Most desirable coding rate of VLC codebooks admitted to the GA list.
E^{best} Most desirable bit entropy of VLC codebooks admitted to the GA list.
T^{best} Most desirable trellis complexity of VLC codebooks admitted to the GA list.
$P^{\max}$ Maximum number of GA mutations.

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Glossary

ACS	Add, Compare and Select
ALU	Arithmetic and Logic Unit
APP	*A Posteriori* Probability
AWGN	Additive White Gaussian Noise
BCH	Bose-Chaudhuri-Hocquenghem
BCJR	Bahl-Cocke-Jelinek-Raviv
BEC	Binary Erasure Channel
BER	Bit Error Ratio
BICM	Bit-Interleaved Coded Modulation
BPSK	Binary Phase Shift Keying
CABAC	Context Adaptive Binary Arithmetic Coding
CAVLC	Context Adaptive Variable Length Coding
CC	Convolutional Coding
COVQ	Channel-Optimised Vector Quantisation
DCMC	Discrete-input Continuous-output Modulated Channel
DCT	Discrete Cosine Transform
EWVLC	Even Weight Variable Length Coding
EXIT	EXtrinsic Information Transfer
FD	Frame Difference
GA	Genetic Algorithm

HA	Heuristic Algorithm
HISO	Hard-In Hard-Out
HMM	Hidden Markov Model
IIR	Infinite Impulse Response
IQ	In-phase Quadrature-phase
IrCC	Irregular Convolutional Coding
IrLDPC	Irregular Low Density Parity Check
IrURC	Irregular Unity Rate Coding
IrVLC	Irregular Variable Length Coding
ISI	InterSymbol Interference
IV-FD	Integer-Valued Free Distance
LBG	Linde-Buzo-Gray
LFSR	Linear Feedback Shift Register
LLR	Logarithmic Likelihood-Ratio
MAP	Maximum *A posteriori* Probability
MB	Macro-Block
MC	Motion Compensation
MIMO	Multiple-In Multiple-Out
ML	Maximum Likelihood
MMSE	Minimum Mean-Squared-Error
MPEG	Motion Picture Experts Group
MSEW	Maximum Squared Euclidean Weight
MSP	Modified Set Partitioning
MUD	Multi-User Detection
PDF	Probability Distribution Function
PSK	Phase Shift Keying
PSNR	Peak Signal to Noise Ratio
QAM	Quadrature Amplitude Modulation
QCIF	Quarter Common Intermediate Format
RV-FDM	Real-Valued Free Distance Metric
RVLC	Reversible Variable Length Coding
SER	Symbol Error Ratio

SIHO	Soft-In Hard-Out
SISO	Soft-In Soft-Out
SNR	Signal to Noise Ratio
SOBIT	SOft BIT
SOVA	Soft Output Viterbi Algorithm
SP	Set Partitioning
SQNR	Signal to Quantisation Noise Ratio
TCM	Trellis Coded Modulation
TCQ	Trellis Coded Quantisation
UEP	Unequal Error Protection
URC	Unity Rate Coding
VB	Video Block
VDVQ	Variable Dimension Vector Quantisation
VLC	Variable Length Coding
VLEC	Variable Length Error Correction
VQ	Vector Quantisation

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