A JOINT SOURCE CHANNEL ARITHMETIC MAP DECODER USING PROBABILISTIC RELATIONS AMONG INTRA MODES IN PREDICTIVE VIDEO COMPRESSION

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Introduction

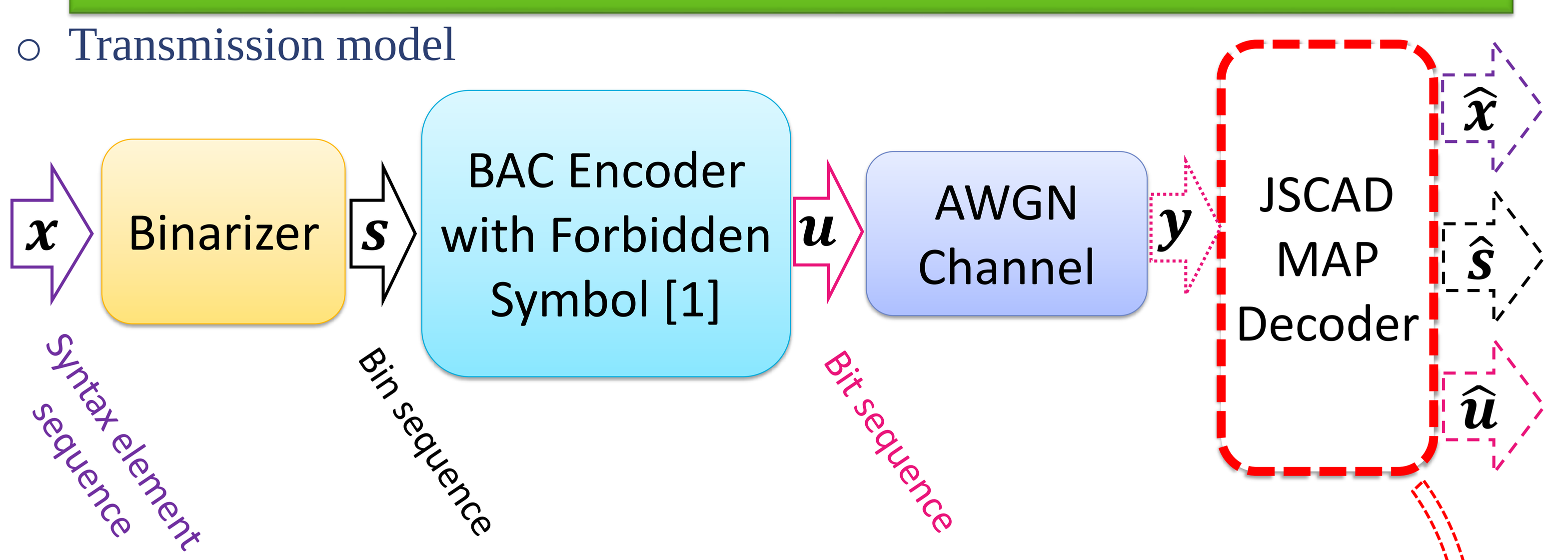
- **Binary Arithmetic coding** (BAC): Entropy coding in recent video compression standards, e.g., **H.264** and high efficiency video compression (**HEVC**)

High compression rate ☺ ↔ Sensitive to Transmission Errors ☹

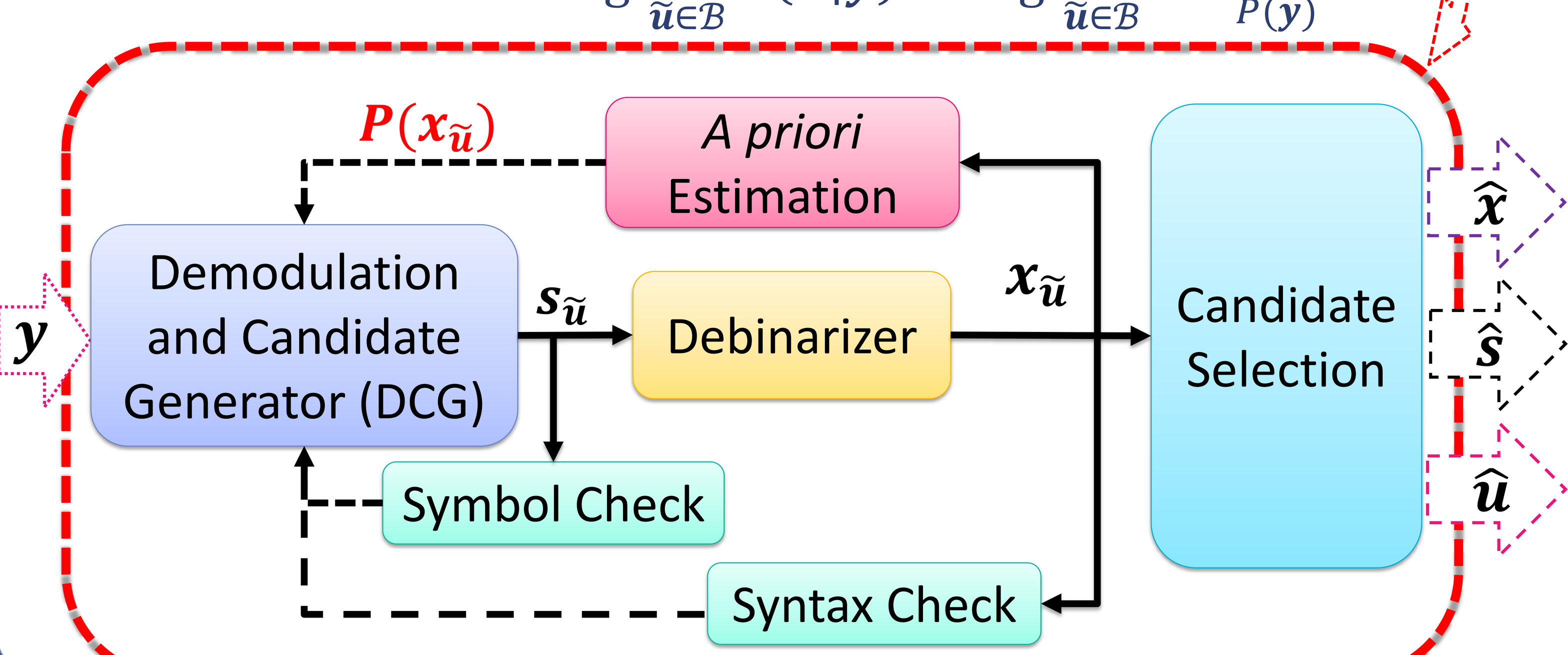
- Solutions:
  - **Channel Coding**
    ☞ Additional redundancy ☹
  - **Error concealment**
    ☞ No error correction ☹
  - ↔ **Joint Source-Channel Arithmetic Decoding (JSCAD)**
    ☞ Exploits *residual redundancy* imposes **NO** overhead ☺
- JSCAD maximum *a posteriori* (MAP) decoder
  - Channel information ➔ channel transition probabilities
  - Prior information ➔ ***a priori* probabilities**
- *A priori* probabilities:
  - Calculated and transmitted ➔ Overhead ☹
  - Use simple fixed models ➔ Not Adaptive ☹
  - A new method proposed for estimation of *a priori probabilities* from previously decoded syntax elements ☺

MAP decoding of JSCAC

- Transmission model

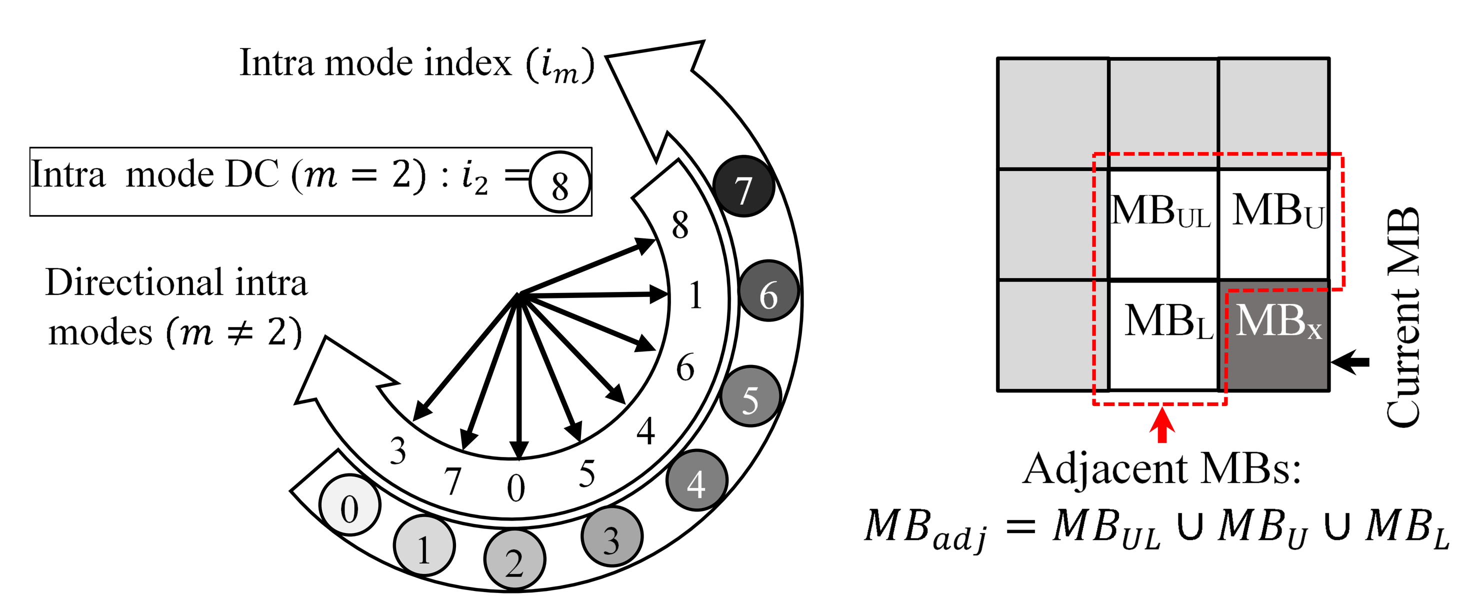


- MAP decoder: $\hat{\boldsymbol{u}} = \arg\max_{\tilde{\boldsymbol{u}}\in\mathcal{B}} P(\tilde{\boldsymbol{u}}|\boldsymbol{y}) = \arg\max_{\tilde{\boldsymbol{u}}\in\mathcal{B}} \frac{P(x_{\tilde{u}})P(\boldsymbol{y}|\tilde{\boldsymbol{u}})}{P(\boldsymbol{y})}$



A priori Probability Estimation of Intra modes

- Calculate probability of every syntax element from the decoded ones
  ☞ $\log\big(P(\boldsymbol{x}_{\tilde{u}})\big) = \log\big(P(\bar{x}_1)\big) + \sum_n \log\big(P(\bar{x}_n|\bar{\boldsymbol{x}}^{n-1})\big)$
- Only interdependency among the spatially adjacent syntax elements
  ☞ $P(\bar{x}_n|\bar{\boldsymbol{x}}^{n-1}) = P(\bar{x}_n|[\![\bar{\boldsymbol{x}}^{n-1}]\!])$



$MB_{adj} = MB_{UL} \cup MB_U \cup MB_L$

$$\hat{P}(M_b = m) = \sum_{m'} \hat{P}(M_{b'} = m')P(M_b = m|M_{b'} = m')$$

ω	0	1	2	3	4
P(Ω=ω)	0.318	0.243	0.175	0.196	0.068

Ω ➔ angular difference between two intra modes in a macroblocks and its neighbors : $\Delta(i, i')$

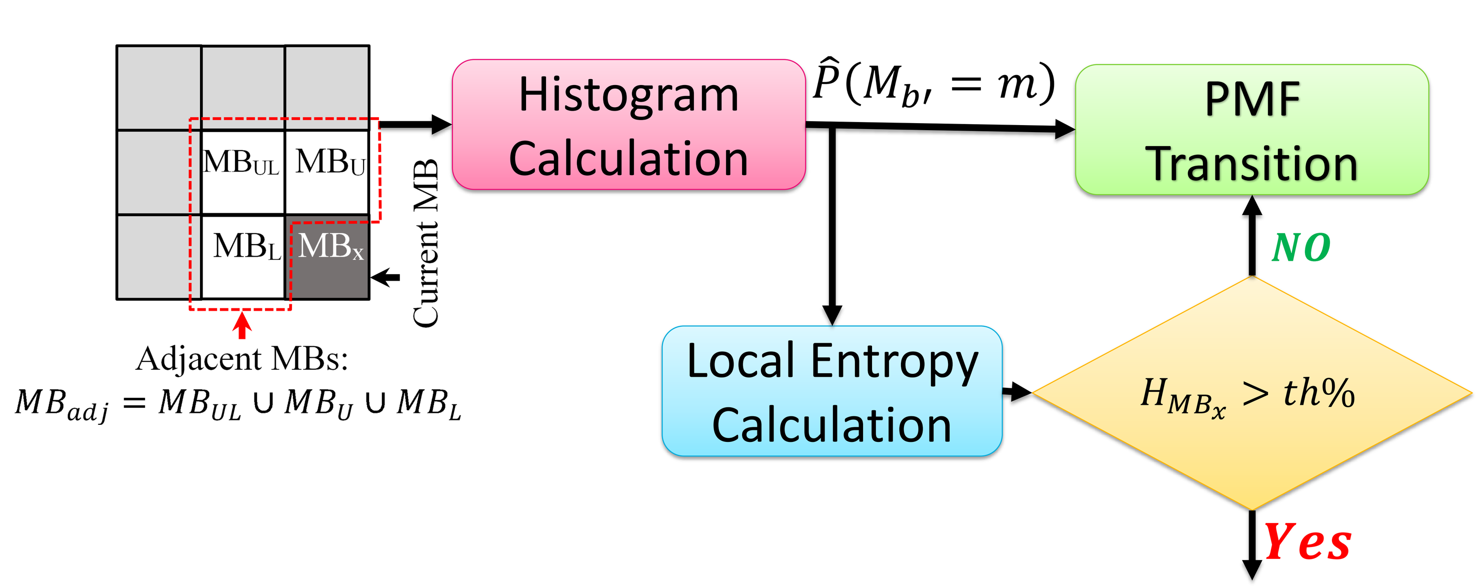
- PMF Transition:

☞ $P(I = i|I' = 8; 0 \le i \le 8) = \frac{1}{9}$

☞ $P(I = i|I' = i'; 0 \le i' \le 7, 0 \le i \le 7) = \begin{cases} \frac{1}{2} \times \frac{8}{9} P(\Omega = \Delta(i,i'))\ 1 \le \Delta(i,i') \le 3 \\ \frac{8}{9} P(\Omega = \Delta(i,i'))\quad \Delta(i,i') = 0 \text{ or } 4\,. \end{cases}$

Adaptive *Intra* Mode Decoding

- Calculate normalized histogram as initial estimation of intra modes PMF
- Categorization to reliable an unreliable based on normalized local entropy
- Calculate intra modes PMF based on $P(\Omega)$



$\hat{P}(M_b = m)$=1/9 ➔Uniform

Simulations and Results

- **Corruption Ratio :** The percentage of decoded frames that have packet error rates (PER) greater than the PER of the Maximum Likelihood (ML) decoder

☞ Average PER Improvement over ML decoder and Corruption Ration for various thresholds in MAP-Ad-Entp for channel SNR is 5.2080 dB

th%	12.50%	25%	37.50%	50%	62.50%	75%	87.50%	100%
PER Improvement %	1.37%	8.90%	13.01%	25.34%	33.56%	36.99%	32.88%	31.51%
Corruption Ratio %	2.97%	5.42%	7.34%	8.90%	9.83%	10.55%	12.09%	13.93%

☞ Video streams are intra encoded using H.264 with quantization parameter (QP) 28

☞ BPSK modulation and various channel SNR

	Video	Method	Channel SNR 4.32 dB	5.2 dB	6.78 dB	7.34 dB	T(sec)
PER	Foreman	ML	9.94E-01	7.76E-01	2.36E-02	3.62E-03	1.2575
		MAP-Ad-Entp-37.5%	9.90E-01	7.34E-01	2.05E-02	3.51E-03	2.07
		MAP-Ad	9.54E-01	5.77E-01	1.23E-02	2.41E-03	2.62
	Car-phone	ML	9.91E-01	7.41E-01	2.21E-02	3.41E-03	1.1825
		MAP-Ad-Entp-37.5%	9.74E-01	6.15E-01	1.50E-02	2.70E-03	2.1525
		MAP-Ad	9.55E-01	5.45E-01	1.05E-02	1.97E-03	2.7
	Crew	ML	9.90E-01	7.37E-01	2.35E-02	3.39E-03	1.2325
		MAP-Ad-Entp-37.5%	9.77E-01	6.95E-01	2.10E-02	3.13E-03	2.05
		MAP-Ad	9.63E-01	6.83E-01	2.41E-02	3.39E-03	2.5875
	Table-tennis	ML	9.90E-01	7.23E-01	2.00E-02	3.04E-03	1.1025
		MAP-Ad-Entp-37.5%	9.85E-01	6.86E-01	1.77E-02	2.75E-03	1.855
		MAP-Ad	9.91E-01	7.41E-01	2.19E-02	2.92E-03	2.49
	Football	ML	9.86E-01	7.45E-01	1.94E-02	2.94E-03	1.3075
		MAP-Ad-Entp-37.5%	9.78E-01	7.37E-01	1.98E-02	2.94E-03	2.205
		MAP-Ad	9.64E-01	7.70E-01	3.54E-02	4.51E-03	2.825
	Average	ML	9.90E-01	7.45E-01	2.17E-02	3.28E-03	1.2165
		MAP-Ad-Entp-37.5%	9.81E-01	6.93E-01	1.88E-02	3.01E-03	2.0664
		MAP-Ad	9.65E-01	6.63E-01	2.08E-02	3.04E-03	2.6444

Conclusion

- A new statistical model has been proposed to estimate *a priori* probabilities in MAP metric to exploit residual redundancy in H.264
- In [2] data stream is decoded codeword-by-codeword using VLC, while in the proposed decoder generates the candidates bit by bit using JSCAC
- PMF of *intra* modes in a MB is estimated adaptively using the SEs located in the spatially adjacent to MBs generated earlier in the decoding tree➔ no Overhead
- The estimation is categorized as either reliable or unreliable ➔the decoder switches adaptively to ML in unreliable cases
- Improvement in PER comparing to ML decoder 1% to 13% at various SNRs
- Future work➔ designing more sophisticated *a priori* probability estimator

References

[1] M. Grangetto, P. Cosman and G. Olmo, "Joint source/channel coding and MAP decoding of arithmetic codes," *IEEE Transactions on Communications*, vol. 53, no. 6, pp. 1007-1016, June 2005

[2] F. Caron and S. Coulombe, "Video error correction using soft-output and hard-output maximum likelihood decoding applied to an H.264 baseline profile," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 7, no. 25, pp. 1161-1174, July 2015