Multiple description source coding with side information

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Motivations

Goals:

- robustness
- good RD performance

Multiple description coding introduces:

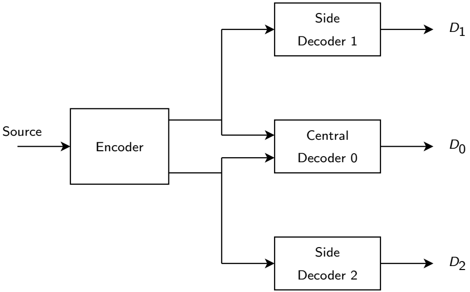
- correlation
- redundancy $\longrightarrow$ bitrate increase

The idea is to exploit at the decoder the correlation with a side information and between the descriptions to limit the rate increase while preserving the robustness properties.

Multiple description coding (MDC) with side information combines:

- Multiple description coding principles
- Slepian-Wolf coding principles

Generic two-description coding scheme



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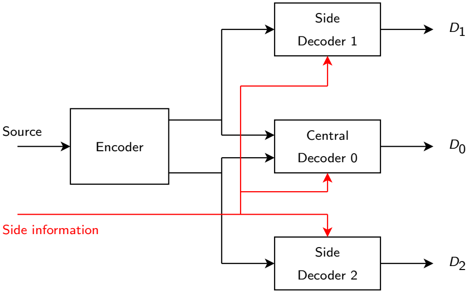
- Slepian-Wolf coding principles

Generic two-description coding scheme with common side information



The rate-distortion region has been defined in [1] as a generalization of the MDC problem to include side information. In the Gaussian case, whether the encoder has access to the side information or not,

$$D_i > \sigma_{\mathcal{F}}^2 2^{-2R_i}, \qquad i \in \{1, 2\} \tag{1}$$

$$D_0 > \frac{\sigma_{\mathcal{F}}^2 2^{-2(R_1+R_2)}}{1 - (\sqrt{\tilde{\Pi}} - \sqrt{\tilde{\Delta}})^2} \tag{2}$$

Where $\sigma_{\mathcal{F}}^2$ is the variance of the MMSE estimation error and

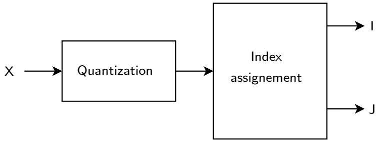
$$\sigma_{\mathcal{F}}^2 = \frac{\sigma_X^2 \sigma_U^2}{\sigma_X^2 + \sigma_U^2}, \quad \tilde{\Pi} = \left(1 - \frac{D_1}{\sigma_{\mathcal{F}}^2}\right)\left(1 - \frac{D_2}{\sigma_{\mathcal{F}}^2}\right),$$

$$\tilde{\Delta} = \left(\frac{D_1}{\sigma_{\mathcal{F}}^2}\right)\left(\frac{D_2}{\sigma_{\mathcal{F}}^2}\right) - 2^{-2(R_1+R_2)}$$

[1] S. N. Diggavi, and V. A. Vaishampayan, 'On multiple description source coding with decoder side information', 2004.

Multiple description scalar quantization (MDSQ) was introduced in [1]. Descriptions are produced by extending quantization techniques with proper index assignment methods.

Multiple description scalar quantization



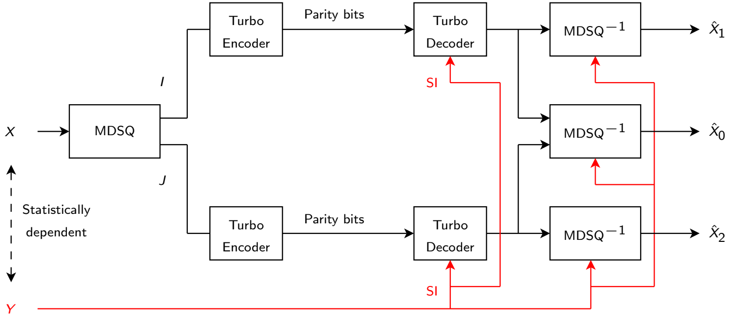
I \ J	0	1	2	3	4	5
0	0					
1	1	2				
2		3	4			
3			5	6		
4				7	8	
5					9	10

The redundancy is controlled by the number of diagonals in the matrix.

[1] V. A. Vaishampayan, 'Design of multiple description scalar quantizers', 1993.

We consider the case where X and Y are two correlated memoryless Gaussian sources where $X = Y + U$. U is a Gaussian noise with zero mean and variance σ_U^2.

MDSQ with common side information scheme



Optimal inverse quantization with side information where the noise U has a Gaussian distribution with variance σ_U^2 is given by

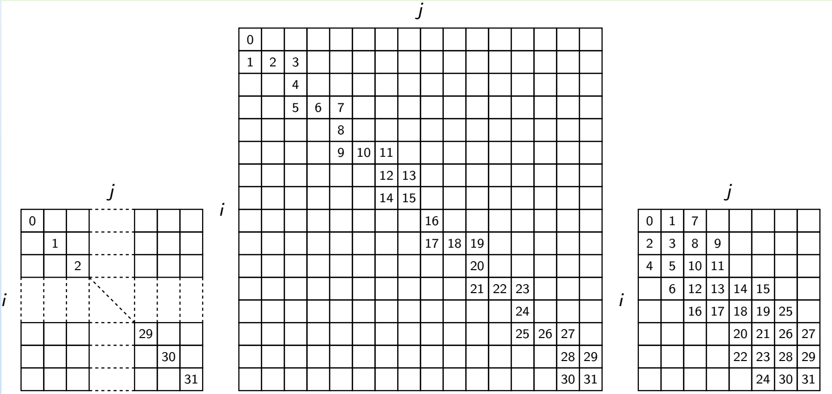
$$\hat{x}_{opt} = E[x|x \in \bigcup_{d=1}^{D} [z_i^d, z_{i+1}^d), y] = \frac{\displaystyle\sum_{d=1}^{D} \int_{z_i^d}^{z_{i+1}^d} x f_{X|Y}(x) dx}{\displaystyle\sum_{d=1}^{D} \int_{z_i^d}^{z_{i+1}^d} f_{X|Y}(x) dx} \quad (3)$$

where D, the number of quantization intervals, depends on the number of descriptions received.

$$\hat{x}_{opt} = y + \frac{\dfrac{\sigma_U \sqrt{2}}{\sqrt{\pi}} \displaystyle\sum_{d=1}^{D} \left(e^{-b^2} - e^{-a^2} \right)}{\displaystyle\sum_{d=1}^{D} (\mathrm{erf}(a) - \mathrm{erf}(b))} \quad \text{where} \quad \begin{array}{rcl} a & = & \frac{z_{i+1}^d - y}{\sigma_U \sqrt{2}} \\ b & = & \frac{z_i^d - y}{\sigma_U \sqrt{2}} \end{array} \quad (4)$$

Results were obtained for 32 quantization intervals and three index assignement matrices that were built using an embedded index assignment strategy [1]. $(2 * k + 1)$ is the number of diagonals.

MDSQ index assignement for central codebook of dimension $Q = 32$, with (a) 1 diagonal, (b) 3 diagonals, (c) 5 diagonals.



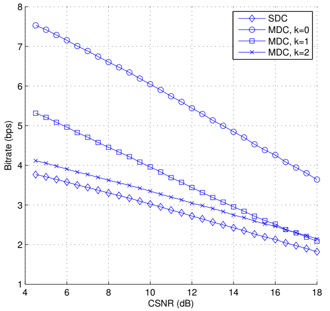
(a) k=0 (b) k=1 (c) k=2

[1] T. Guionnet, C. Guillemot, S. Pateux, 'Embedded multiple description coding for progressive image transmission over unreliable channels', 2001.

The Slepian-Wolf theorem tells us that the theoretical bitrate limit is defined as:

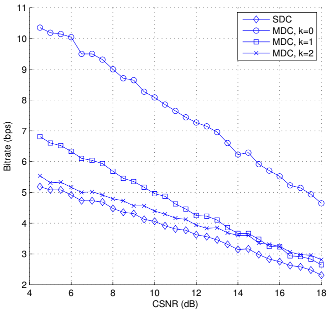
$$R_X \geq H(I|Y) + H(J|Y) \tag{5}$$

Theoretical minimum number of bits per symbol comparison of the SDC and MDC schemes.

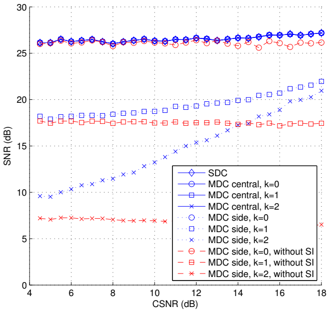


The impact of the CSNR (σ_Y^2/σ_U^2) diminishes when k becomes larger because the correlation between Y and I, J not only depends on the CSNR but also on k.

Rate comparison of the SDC and MDC schemes.



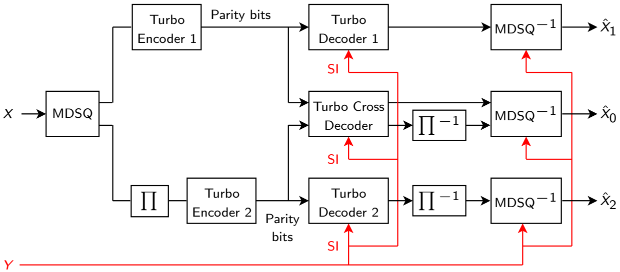
SNR comparison of the SDC and MDC schemes.



Side decoders benefit from the knowledge of the SI even at very low CSNR values

Why not exploit the correlation between the descriptions at the central turbo decoder?

MDSQ with common side information scheme with cross-decoding



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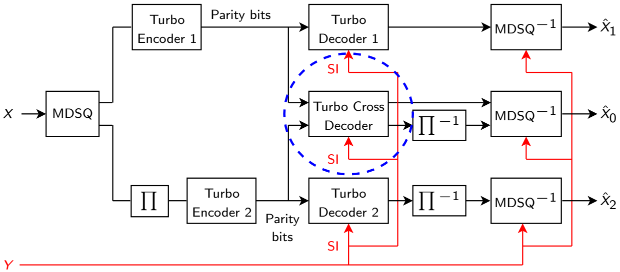
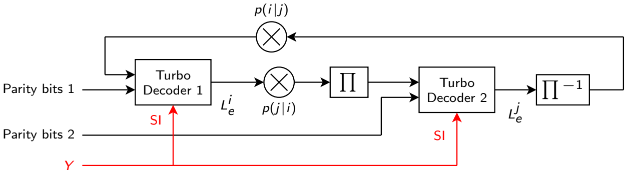


It was proposed in [1] to use iterative decoding techniques similar to those used in turbo decoding to decode multiple correlated descriptions.

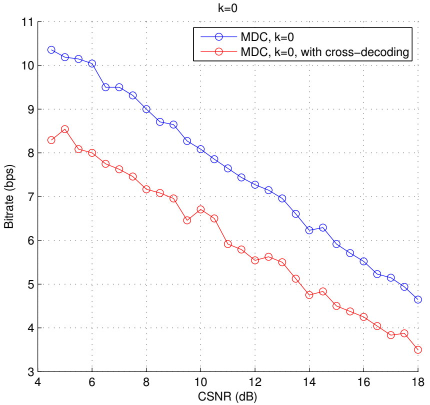
Turbo cross-decoding



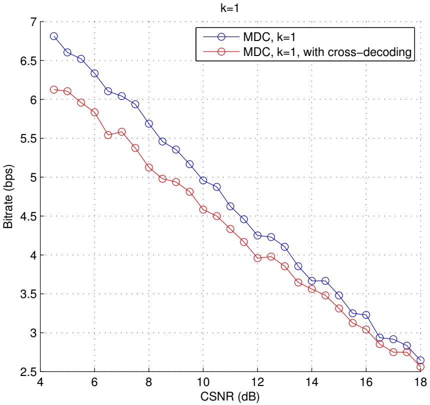
The decoder combines the extrinsic information L_e^i and L_e^j with the two conditional probability distributions $P(j|i)$ and $P(i|j)$ and send the results as *a priori* informations to the turbo decoders of i and j repectively.

[1] M. Srinivasan, 'Iterative decoding of multiple descriptions', 1999

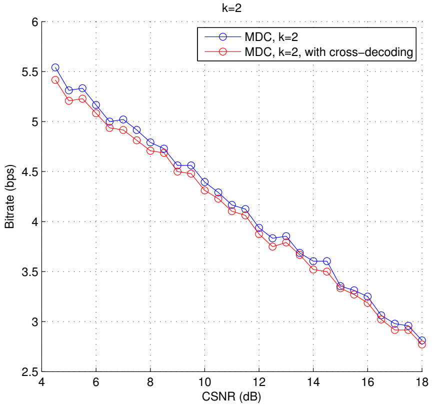
Rate comparison of the MDC schemes with and without cross-decoding for $k = 0$.



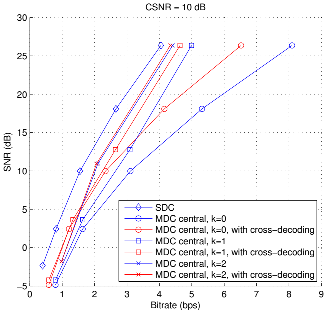
Rate comparison of the MDC schemes with and without cross-decoding for $k = 1$.



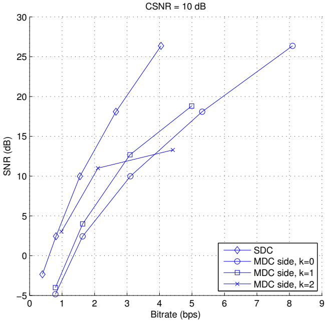
Rate comparison of the MDC schemes with and without cross-decoding for $k = 2$.



Central rate-distortion comparison of the SDC and MDC schemes for a CSNR value of 10 dB.



Side rate-distortion comparison of the SDC and MDC schemes for a CSNR value of 10 dB.



Each point on the curves was obtained for a different number of bitplanes perfectly decoded.

The proposed robust multiple distributed coding scheme has interesting properties:

- Balanced MDC scheme
- Robustness comes at a moderate rate cost thanks to:
  - the use of coding with side information
  - the cross-decoding at the central decoder

Perspectives in distributed video coding:

- No drift like in predictive MDC
- Keeps a low encoder complexity

THANK YOU