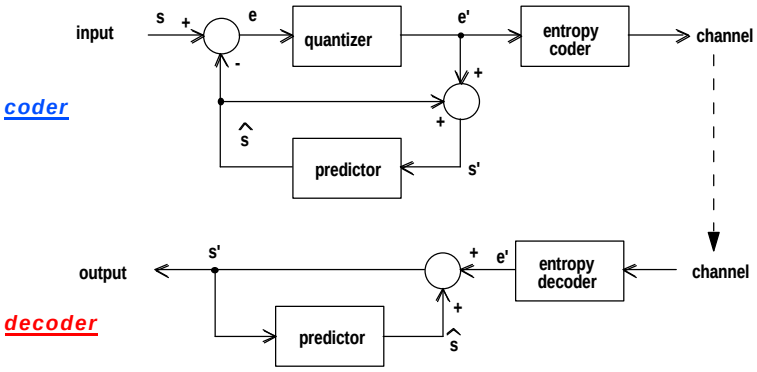
DPCM - Overview

- Principle of Differential Pulse Code Modulation (DPCM)
- Characteristics of DPCM quantization errors
- Adaptive intra-interframe DPCM
- Conditional Replenishment

Principle of DPCM



Prediction error

$$e = s - \hat{s}$$

Reconstruction

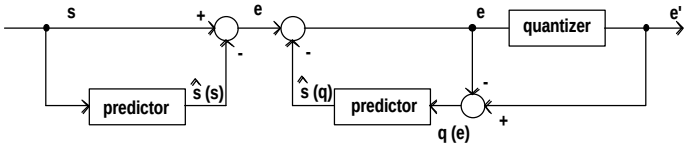
$$s' = e' + \hat{s}$$

Reconstruction error = quantization error

$$s' - s = e' - e = q$$

Quantization error feedback in the DPCM coder

- Assuming a linear predictor, the DPCM coder is equivalent to the following structure:



- Transfer function of the prefilter:

$$\tilde{E}(\Omega) = [1 - P(\Omega)]S(\Omega)$$

Ω - abbreviation for frequency vector, e.g., (w_x, w_y)

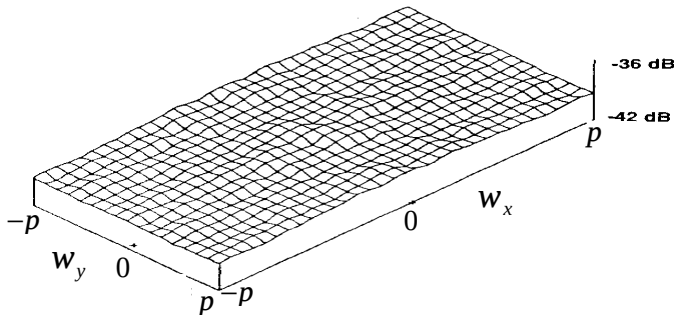
transfer function of the predictor

- Transfer function of quantization error feedback:

$$E'(\Omega) = \tilde{E}(\Omega) + [1 - P(\Omega)]Q(\Omega)$$

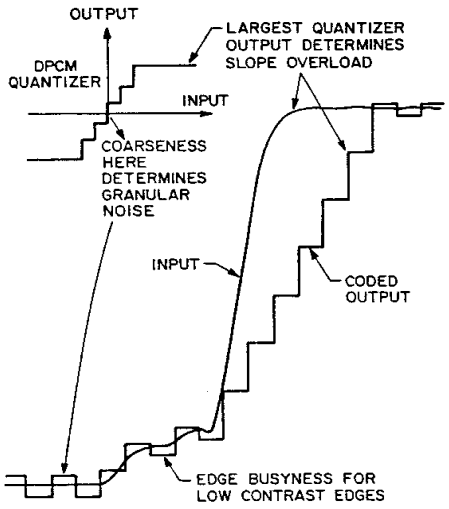
Power spectrum of the DPCM quantization error

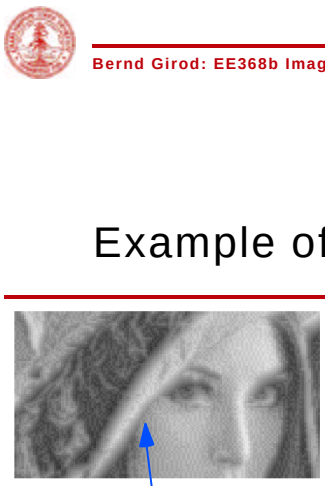
- Power spectral density of the quantization error q measured for intraframe DPCM with a 16 level quantizer



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.





Example of intraframe DPCM coding

1 bit/pixel
prediction error coding

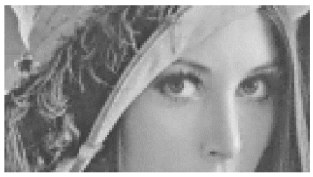

2 bit/pixel

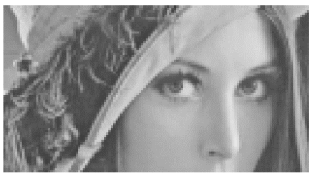

3 bit/pixel

edge busyness

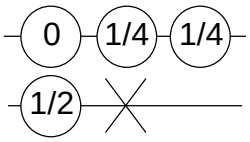
slope overload

granular noise


4 bit/pixel


original

- Linear predictor:



- Lloyd-Max quantizers
- Fixed-length coding

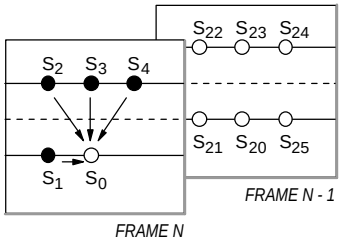
Interframe coding of video signals

- Interframe coding exploits:
  - similarity of temporally successive pictures
  - temporal properties of human vision
- Important interframe coding methods:
  - Adaptive intra-interframe coding
  - Conditional replenishment
  - Motion-compensated prediction
  - Motion-compensated interpolation

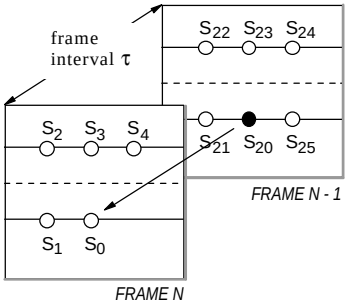
Principle of adaptive intra-interframe DPCM

- Predictor is switched between two states:

A: Intraframe prediction for moving or changed areas.



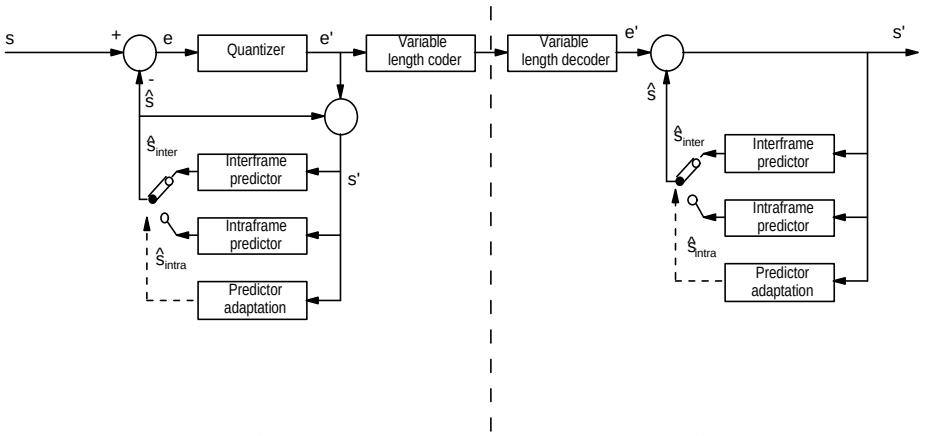
B: Interframe prediction (previous frame prediction) for still areas of the picture.



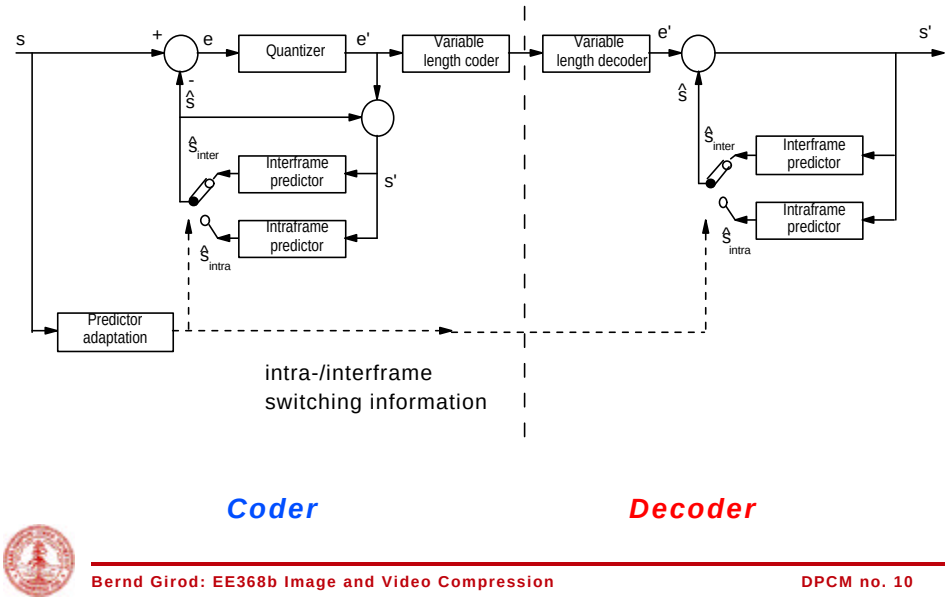
$$\hat{S}_{\text{intra}} = a_1 S_1 + a_2 S_2 + a_3 S_3 + a_4 S_4$$

$$\hat{S}_{\text{inter}} = S_{20}$$

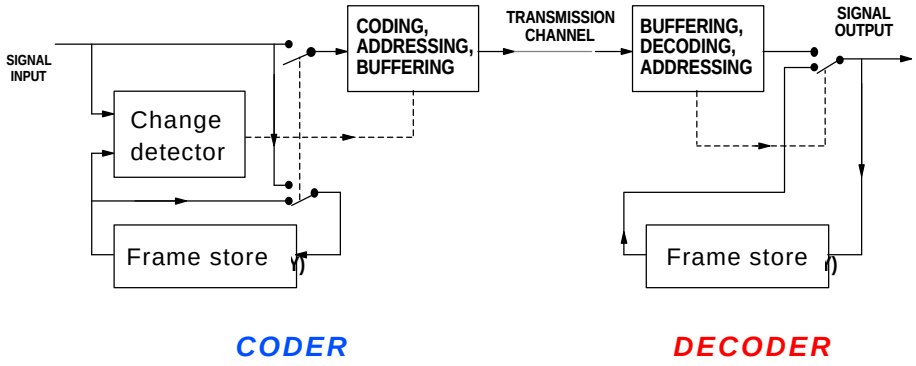
Intra-interframe DPCM: feedback adaptation



Intra-interframe DPCM: feedforward adaptation



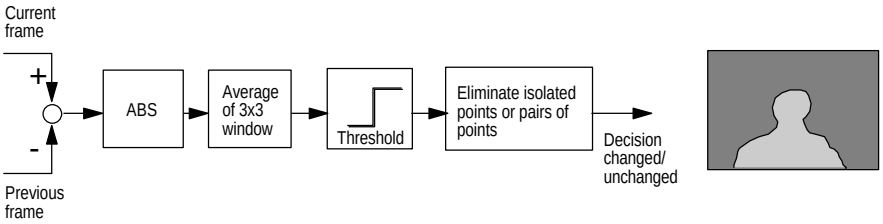
Conditional replenishment



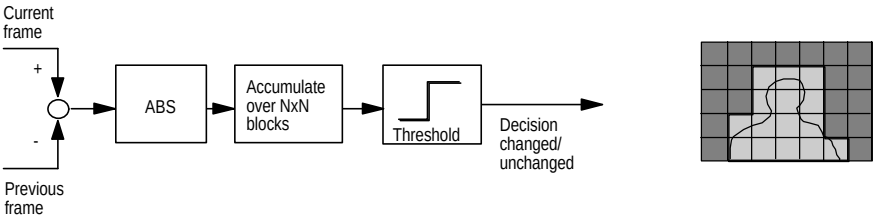
- Still areas: repeat from frame store
- Moving areas: encode and transmit address and waveform

Change detection

- Example of a pixel-wise change detector

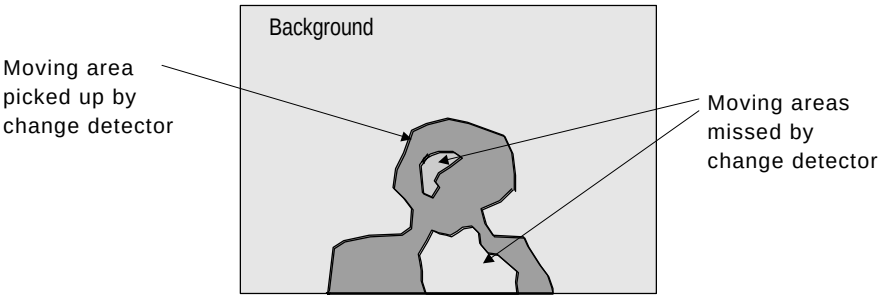


- Example of a block-wise change detector

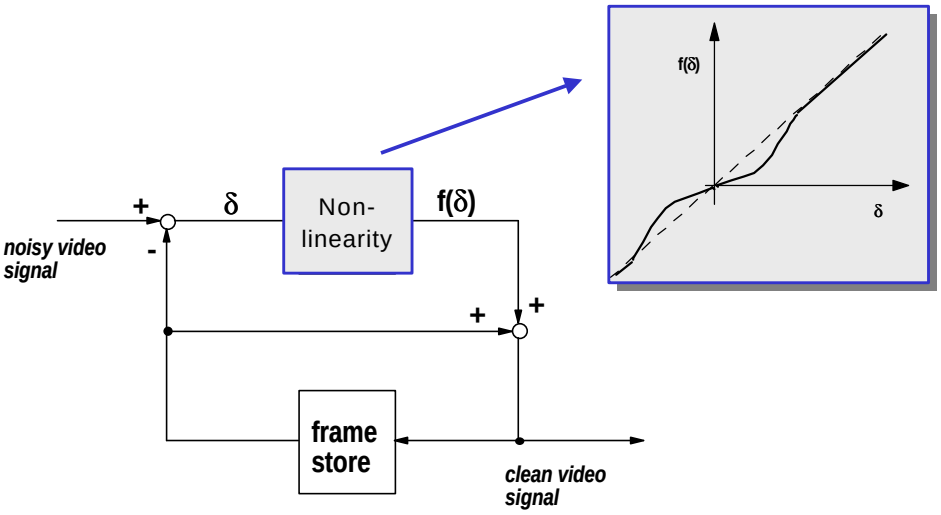


The “Dirty Window” effect

- Conditional replenishment scheme with change detection threshold set too high leads to the subjective impression of looking through a dirty window.



Crawford noise reduction filter



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
- 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