Wyner-Ziv Coding and Project Topics for EE398B

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(Joint work with the IVMS Group)

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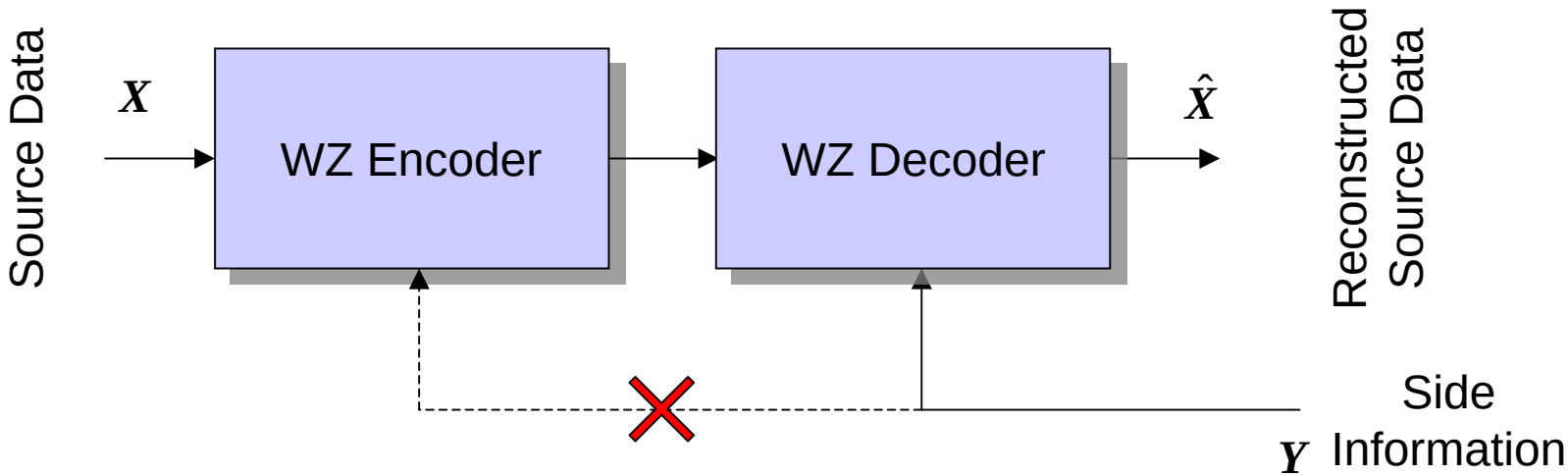
Outline

- Wyner-Ziv Coding
  - Definition
  - Applications to video
  - My research in the IMVS group
- Project topics
  - Motion compensation for Wyner-Ziv video coding
  - High-rate quantization with unconditional entropy constrain (time permitting)

Wyner-Ziv (WZ) Coding

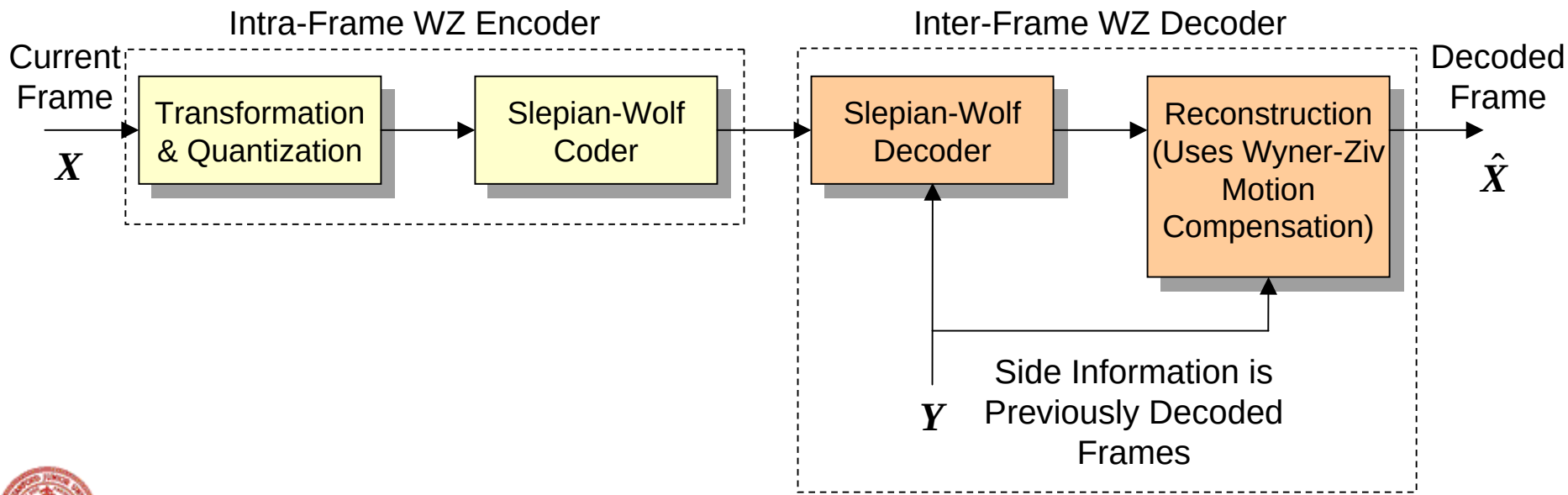
- WZ coding is lossy source coding with side information
  - Values of side information available at the decoder only
  - Joint statistics known by both encoder and decoder



- Lossless version corresponds to Slepian-Wolf coding
- Rate-distortion theory for distributed source coding suggests small performance loss [Slepian, Wolf, 73] [Wyner, Ziv, 76] [Zamir, 96]

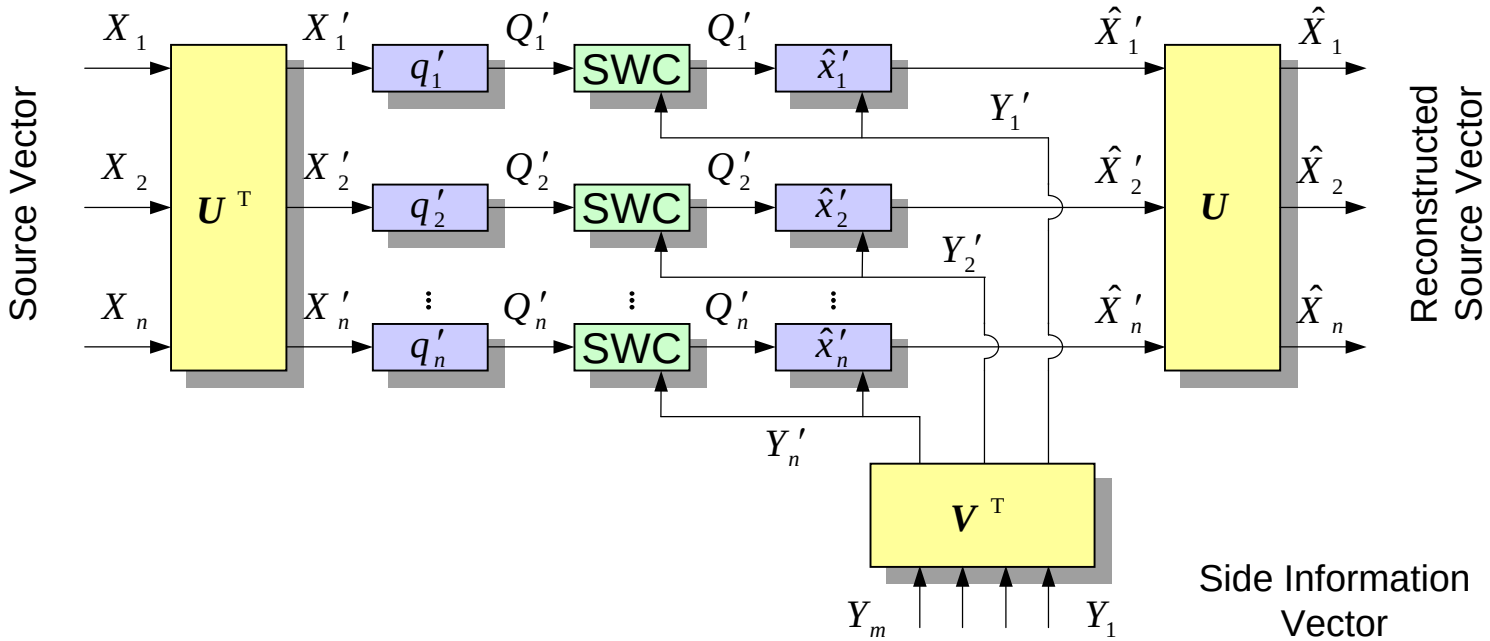
Applications to Video

- Video coder design with complexity constraint
  - Low-complexity encoder (e.g., portable device)
  - Possibly high-complexity decoder (e.g., central station)
  - Conventional video encoders are more complex than decoders!
- WZ coding can be used
  - Lossless coding, quantization and transforms already studied
  - How to perform motion compensation at the decoder? [Girod]



My Research in the IVMS Group

- Theoretical WZ coding
  - Quantization design and high-rate characterization
  - Transform coding
  - Network quantization of noisy observations of unseen sources
  - Statistical inference with side information
- Applications to video



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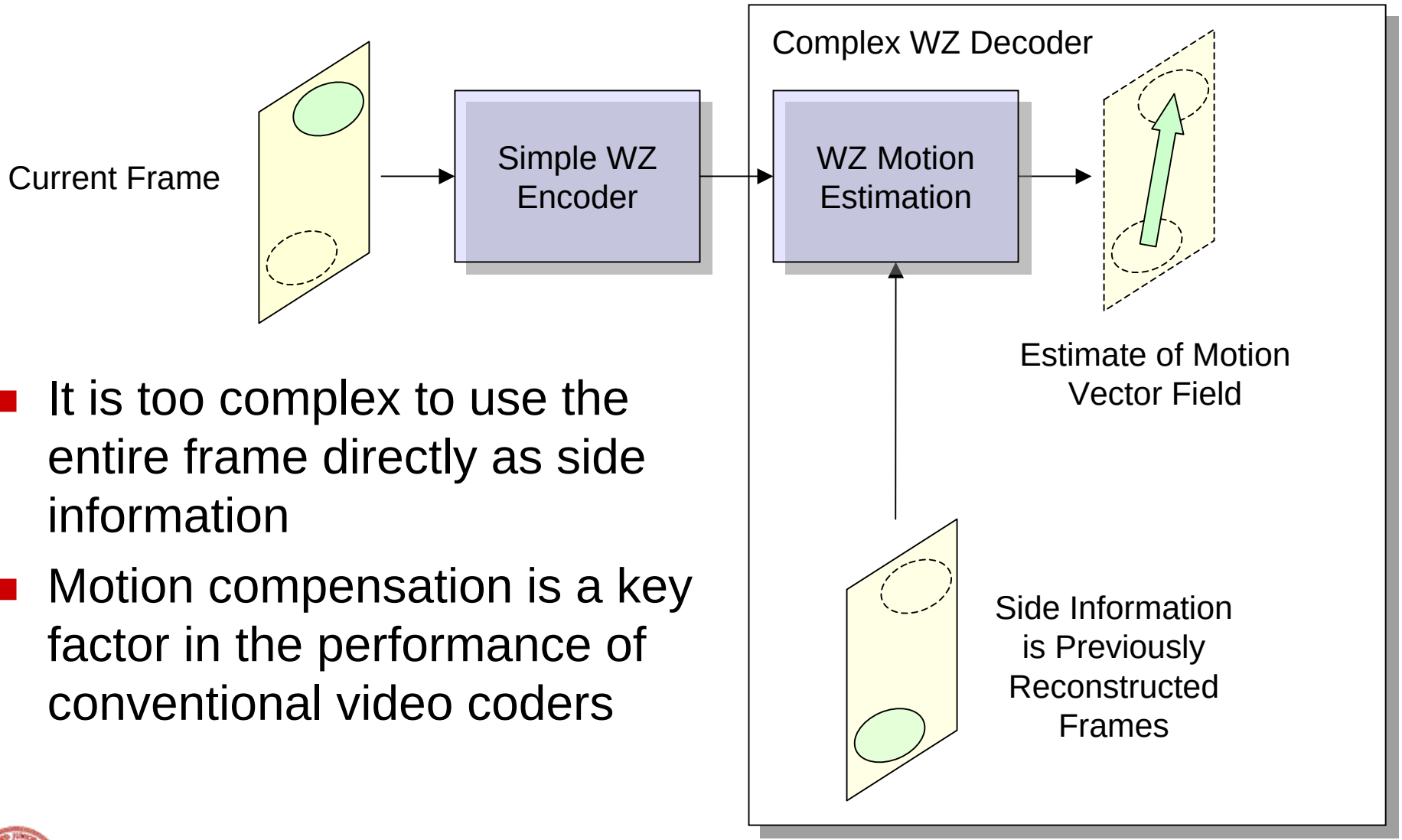
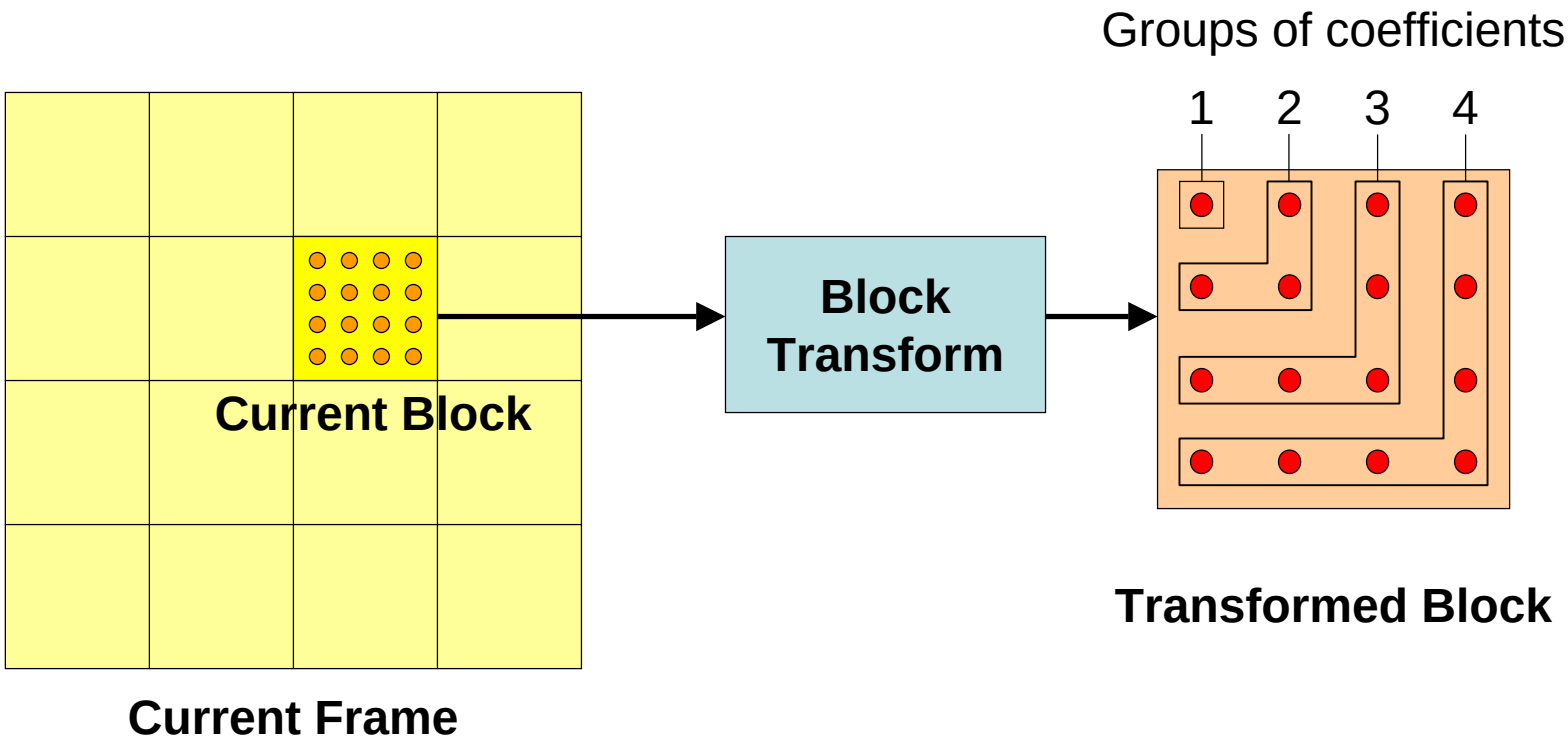
WZ Motion Estimation



- It is too complex to use the entire frame directly as side information
- Motion compensation is a key factor in the performance of conventional video coders

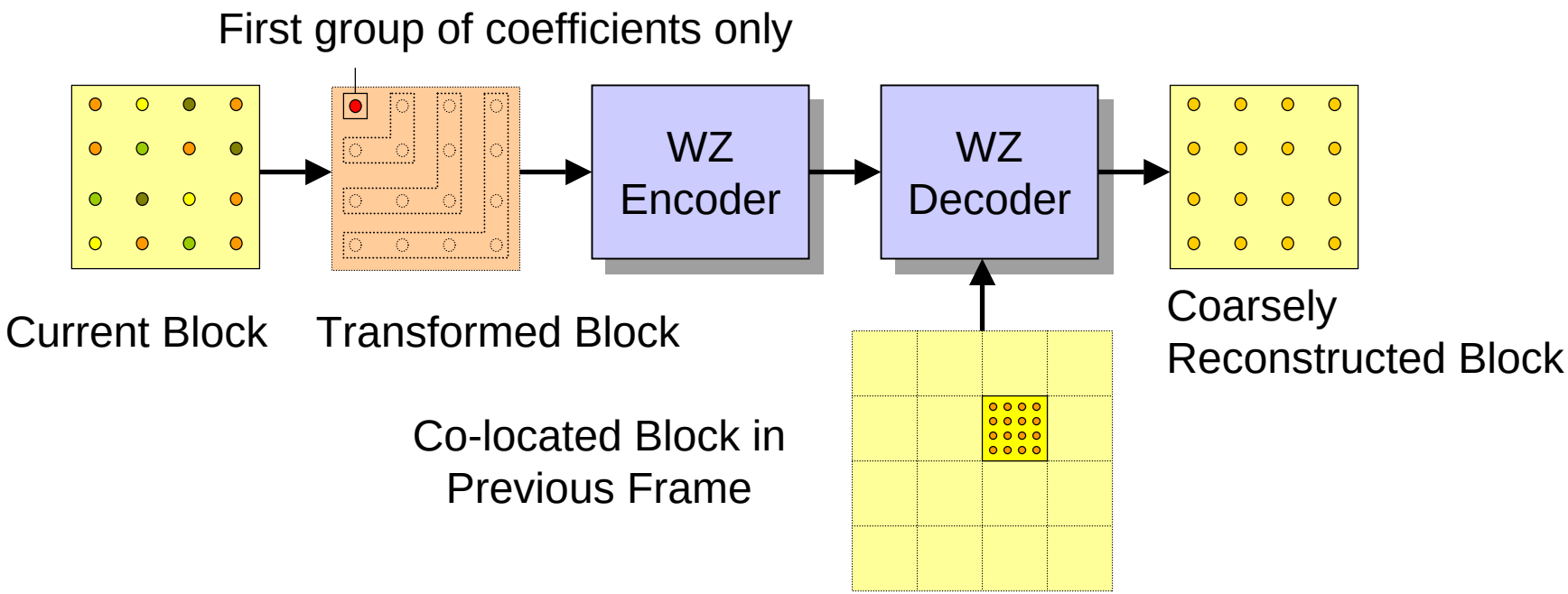
WZ Video Coding with Increasingly Accurate Motion-Compensated Side Information (I)

- Divide current frame into blocks
- Transform each block
- Group transformed coefficients and sort groups



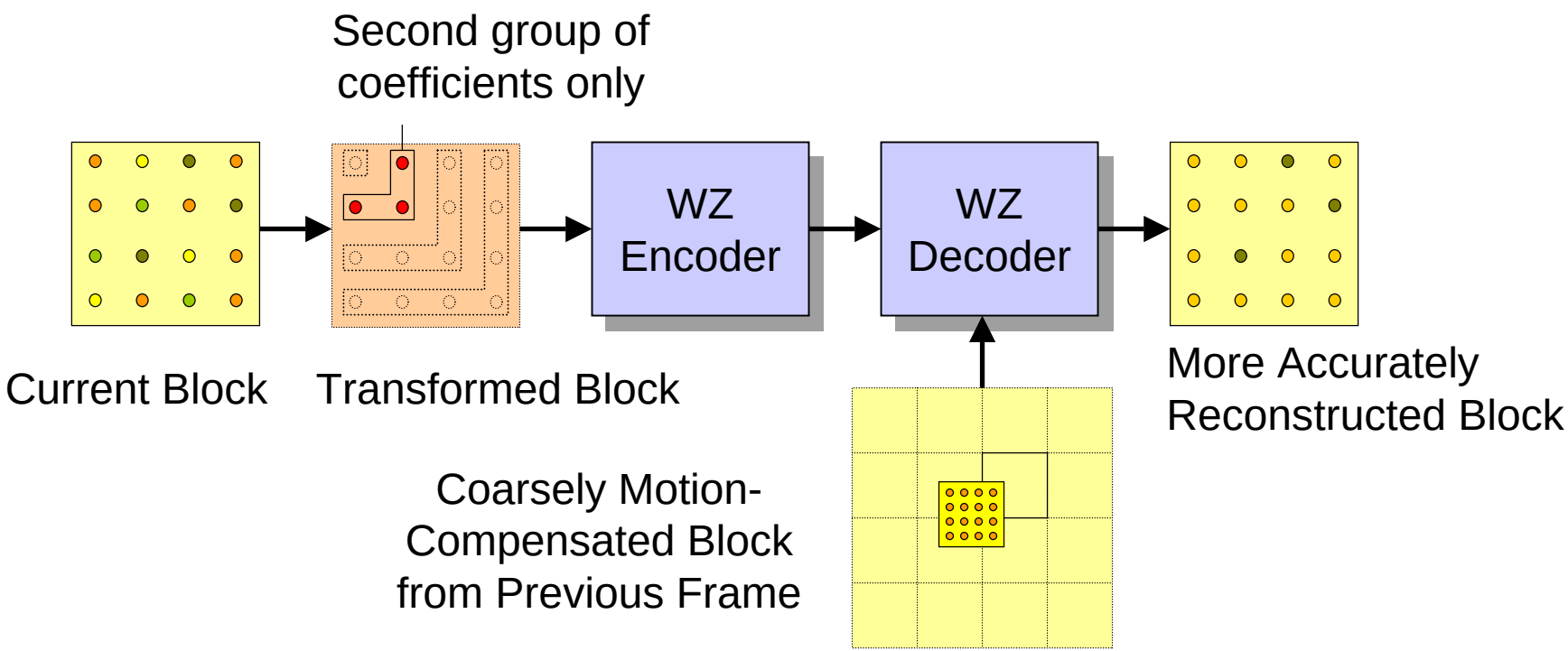
WZ Video Coding with Increasingly Accurate Motion-Compensated Side Information (II)

- WZ coding of the block is performed in stages
- **First** stage
  - Side information is co-located block in previously reconstructed frame
  - First group of transformed coefficients is WZ coded
  - Coarse reconstruction is available at the decoder



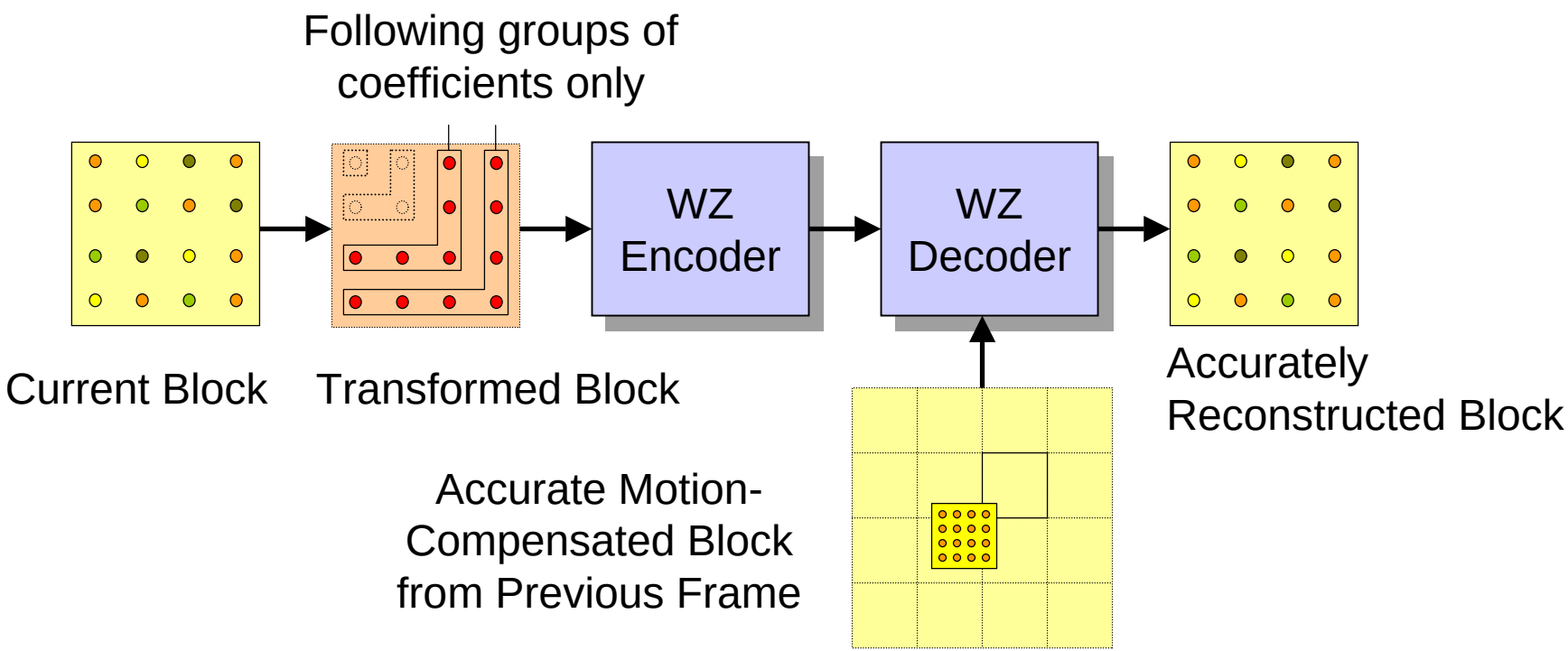
WZ Video Coding with Increasingly Accurate Motion-Compensated Side Information (III)

- **Second** stage
  - Coarse reconstruction used for coarse motion compensation of side information
  - Second group of transformed coefficients are WZ coded
  - More accurate reconstruction is available at the decoder



WZ Video Coding with Increasingly Accurate Motion-Compensated Side Information (IV)

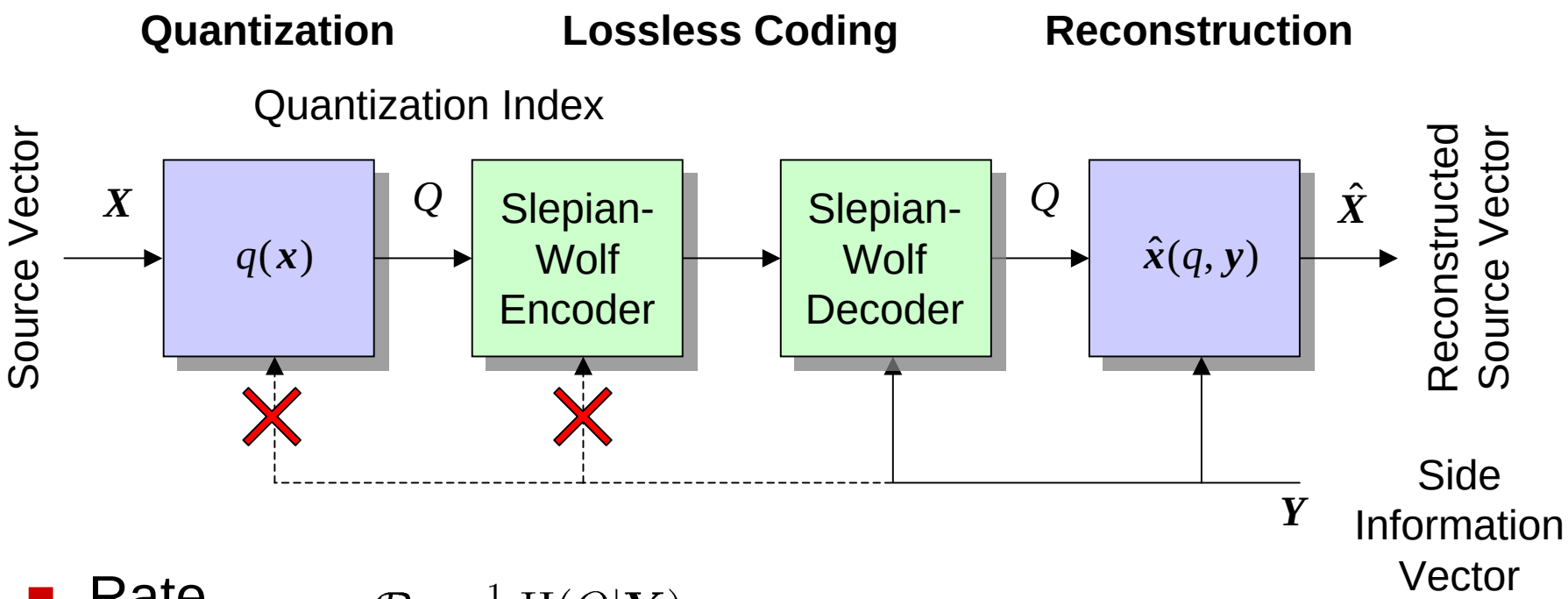
- **Following** stages
  - Partial reconstructions used for increasingly accurate motion compensation of side information
  - Sub-pixel, variable-block-size motion compensation may be used
  - Following groups of transformed coefficients are WZ coded



WZ Video Coding with Increasingly Accurate Motion-Compensated Side Information (V)

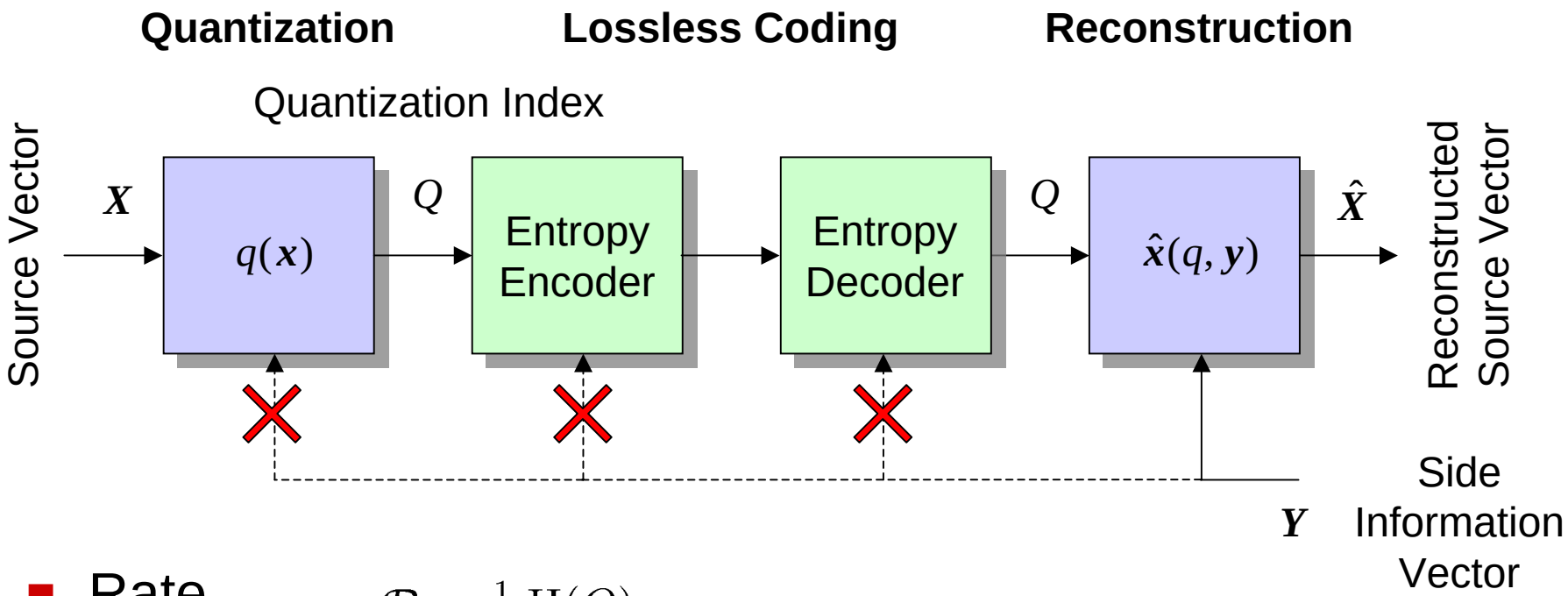
- Intuition
  - Take advantage of partial reconstructions to refine side information
  - Having and accurate reconstruction of the block and accurate motion-compensated side information are roughly equivalent
  - More accurate motion compensation is required for coefficients at higher frequencies
  - The higher the number of stages, the higher the performance but also the decoder complexity
- Additional information can be sent by the encoder to help the motion estimation [Girod]
  - 'Hash' retaining useful information from the current block
  - For instance, based on a few subsamples in the pixel domain, or in the transform domain, coarsely quantized
  - At the first stage, or at each stage of the previous method

WZ Quantization



- Rate $\mathcal{R} = \frac{1}{n} \mathrm{H}(Q|\boldsymbol{Y})$
- Distortion $\mathcal{D} = \frac{1}{n} \mathrm{E}[\|\boldsymbol{X} - \hat{\boldsymbol{X}}\|^2]$
- High-rate characterization
  - Lattice quantizers
  - No two cells mapped into same quantization index

WZ Quantization with Unconditional Entropy Constraint



- Rate $\mathcal{R} = \frac{1}{n} \mathrm{H}(Q)$
- Distortion $\mathcal{D} = \frac{1}{n} \mathrm{E}[\|\boldsymbol{X} - \hat{\boldsymbol{X}}\|^2]$
- High-rate characterization
  - Unknown
  - May give intuition on the design of nearly-lossless codes

To Do

- Check this and other topics, also on WZ video coding at http://www.stanford.edu/class/ee398b/topics.htm
- If interested in my topics, contact me at drebollo@stanford.edu
- I'll stick around after class