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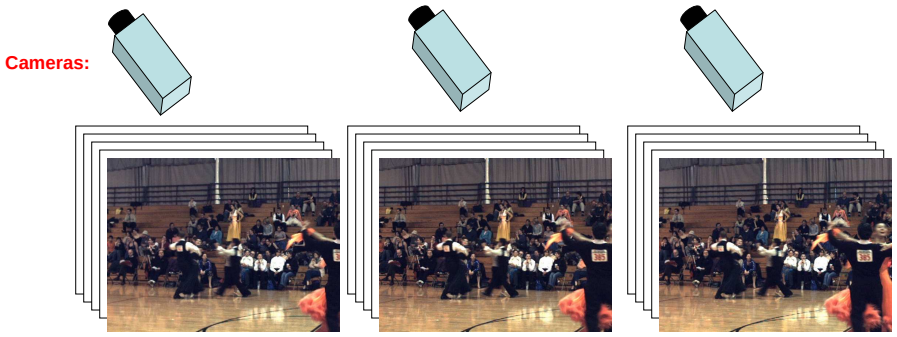
Distributed Source Coding Application to Low-Delay Free Viewpoint Switching in Multiview Video Compression



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University of Southern California, Los Angeles, CA, USA

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Free Viewpoint Switching in Multiview Video

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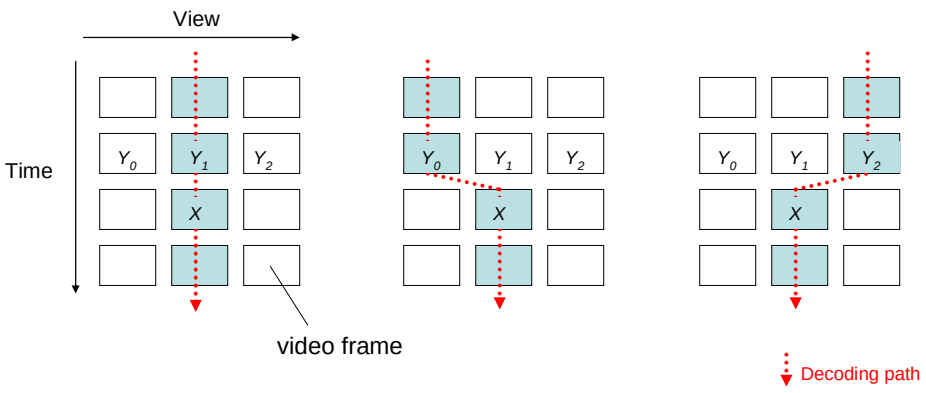
Users select a particular view:

Users switch between different views during playback:



In order to address viewpoint switching, compression schemes have to support **multiple decoding paths**

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Free viewpoint switching poses challenges to multiview compression

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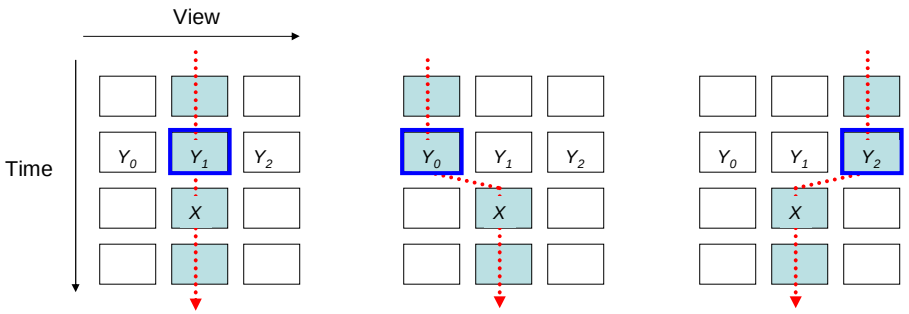
When users can choose among different decoding paths, it is not clear which previous reconstructed frame will be available to use in the decoding



Multiple decoding paths ⇒ Either Y_0 or Y_1 or Y_2 will be available at decoder ⇒ Uncertainty on predictor status at decoder!!!!

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Problem Formulation

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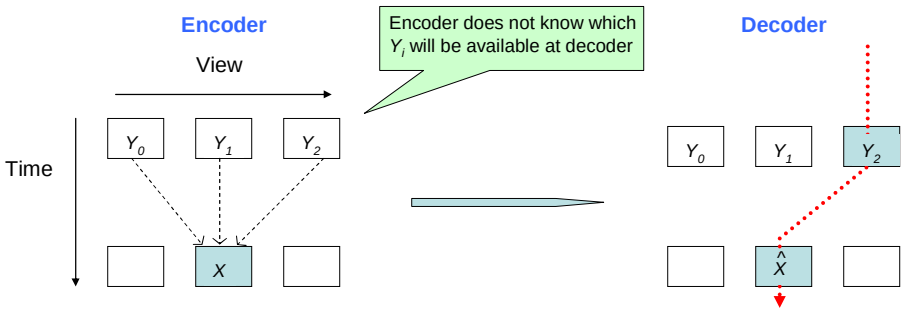
To support low-delay free viewpoint switching, encoder needs to operate under uncertainty on decoder predictor



- Assume feedback is not available
  - Low-delay, interactive application
  - Offline encoding of multiview data

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Address Viewpoint Switching Within Closed-Loop Predictive (CLP) Coding Framework

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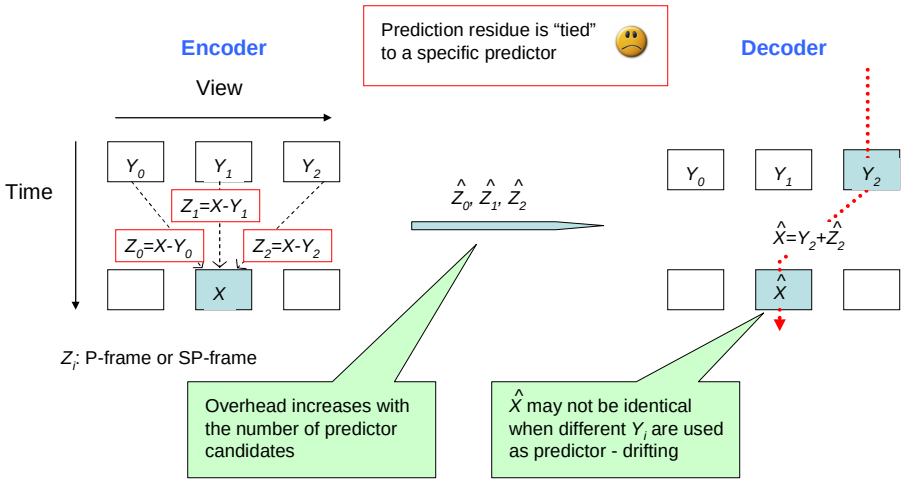
Encoder has to send **multiple** prediction residues to the decoder



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Our Contributions

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- Extend our previous work on video compression with decoder predictor uncertainty [Cheung, Ortega; MMSP 07]
- Propose distributed source coding (DSC) based coding algorithm to address viewpoint switching
- **Apply DSC to generate a *single* bitstream that can be decoded in *several* different ways**
- Propose an efficient encoding algorithm
  - Macroblock mode
  - Significance coding
  - Correlation model
  - Minimum MSE dequantization

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Related Work

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Differences between our work and distributed multiview coding

(E.g., [Zhu, Aaron, Girod; SSP 03], [Toffetti, Tagliasacchi, Marcon, Sarti, Tubaro, Ramchandran; EUSIPCO 05])

	Distributed multiview image/video coding	**Free viewpoint switching**
Key objective	Distributed, independent encoding at spatially-separated sensors	Centralized encoding to generate a single bitstream to support multiple decoding paths
Encoder complexity	Low-complexity encoding	Not primary issue. Applications use off-line encoding
Encoder access to SI	SI not accessible	Encoder has access to all SI candidates

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Related Work

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- Provide random access in compression of image-based rendering data/multiview video
  - [Jagmohan, Sehgal, Ahuja; Asilomar 03]
  - [Aaron, Ramanathan, Girod; MMSP 04]
  - [Guo, Lu, Wu, Gao, Li; VCIP 06]
  - **All assume encoder has knowledge on predictor status, e.g., using feedback**
- Robust video transmission [Wang, Prabhakaran, Ramchandran; ICIP 06]
  - Specific algorithms used are different
- Improve decoding flexibility and accessibility [Naman, Taubman; ICIP 07]
  - Feedback and conditional replenishment
- Forward/backward video playback [Cheung, Wang, Ortega; VCIP 06]
  - Considerably different algorithm to achieve better coding performance

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Solution Based on Distributed Source Coding

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DSC - Virtual Communication Channel Perspective

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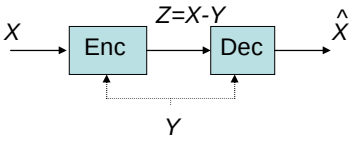
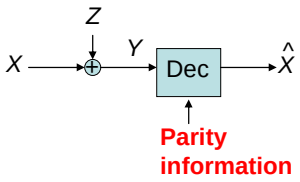
In DSC, encoder can communicate *X* by sending **parity information**
(E.g., [Girod, Aaron, Rane, Rebollo-Mondero; Proc. IEEE 04])

CLP:



DSC:



Parity information is **independent** of a specific predictor
- What matters is the **amount** of parity information

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Address Viewpoint Switching Using DSC

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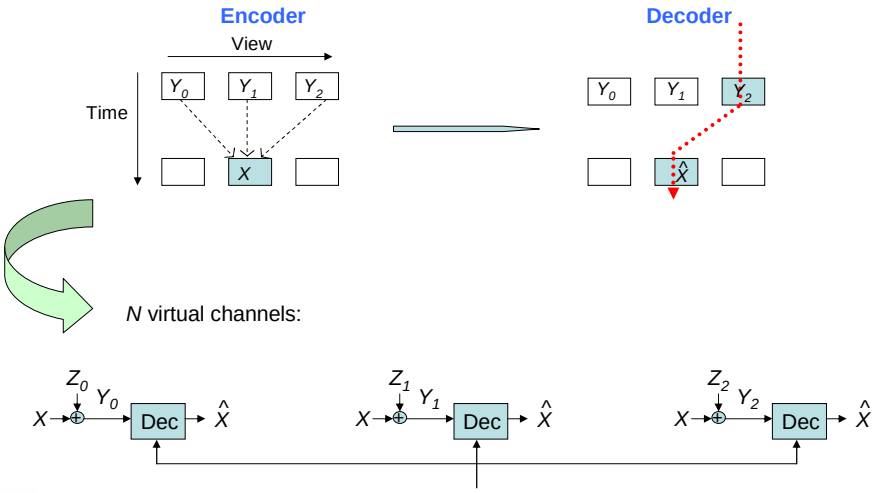
Under predictor uncertainty, encoder can communicate X by sending an amount of parity corresponding to the **worst case correlation**



Viewpoint Switching: CLP vs. DSC

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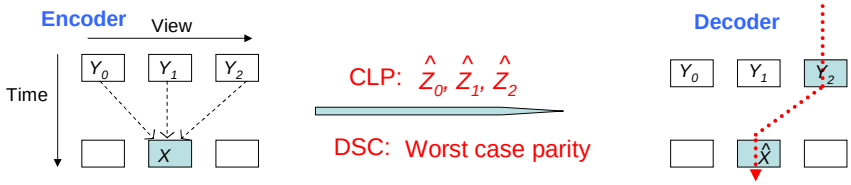
CLP

$R_{CLP} = sum\ (\ H(Z_i)\ )$

$H(Z_0)$ $H(Z_1)$ $H(Z_2)$



DSC

$R_{DSC} = max\ (\ H(Z_i)\ )$

$H(Z_0)$

$H(Z_1)$

$H(Z_2)$

Bits required to communicate X with Y_i at decoder : $H(X \mid Y_i) = H(Z_i)$

Viewpoint Switching: CLP vs. DSC

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CLP

$R_{CLP} = sum\ (\ H(Z_i)\ )$

$H(Z_0)$ $H(Z_1)$ $H(Z_2)$

Encoder View

Time

Y_0 Y_1 Y_2

X

CLP: $\hat{Z}_0, \hat{Z}_1, \hat{Z}_2$

DSC: Worst case parity

Decoder

Y_0 Y_1 Y_2

$\hat{X}$

DSC

$R_{DSC} = max\ (\ H(Z_i)\ )$

$H(Z_0)$

$H(Z_1)$

$H(Z_2)$

Bits required to communicate X with Y_i at decoder : $H(X \mid Y_i) = H(Z_i)$

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Encoding Algorithm – Motion Estimation and Macroblock Classification

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M may be classified to be in a *skip* mode if the difference between M and predictors from some f_i is small

Input current frame

M

Motion estimation/ MB classification

Motion vector information

skip

non-skip

CLP

DSC

Candidate reference frames: $f_0, f_1, f_2, \ldots, f_{N-1}$

Mode decision

Output bitstream

Majority: using DSC

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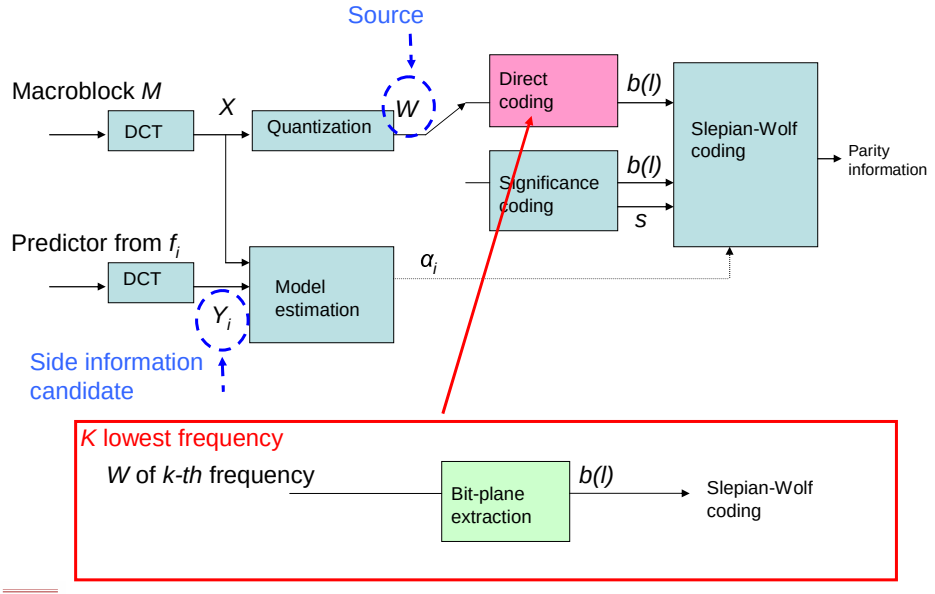
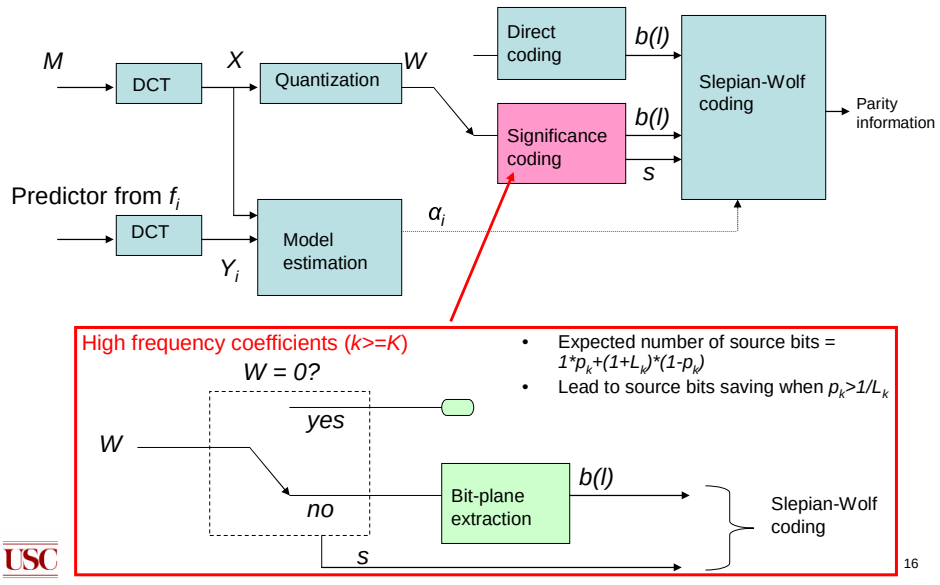
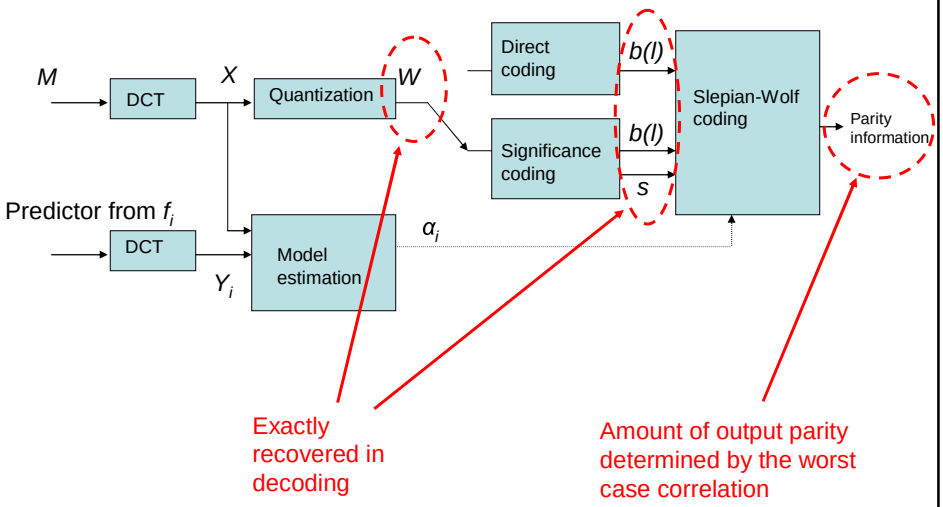
Encoding Algorithm – DSC Coded MB



Encoding Algorithm – Significance Coding

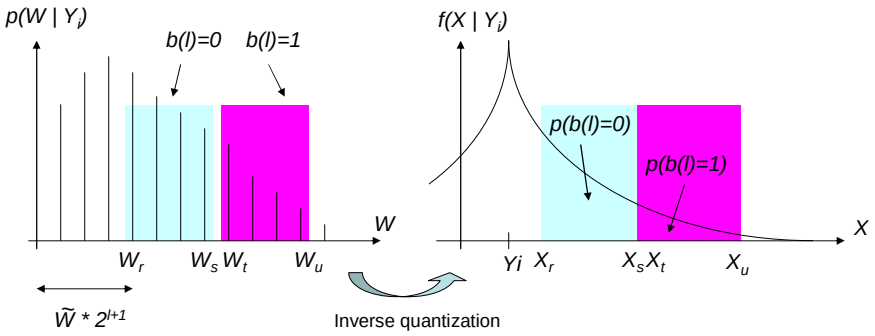


Drift-free: *W* in DSC coded MB are exactly recovered



Model and Conditional Probability Estimation

Estimate $p(b(l) \mid Y_i, b(l+1), b(l+2), \ldots)$ by integrating $f(X \mid Y_i)$ as follow:



Experimental Results - Multiview Video Coding

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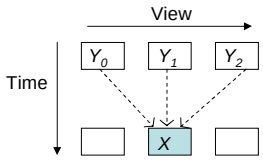
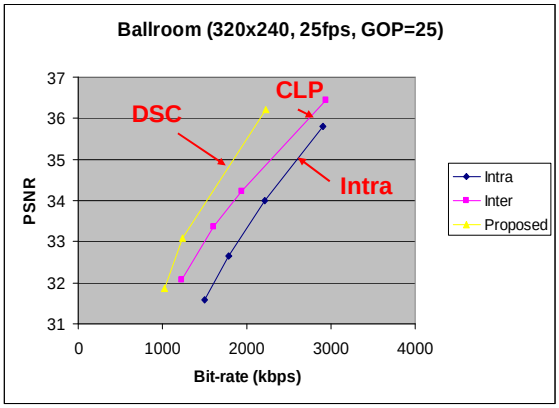
Allow switching from adjacent views: three predictor candidates





Our proposed algorithm out-performs CLP and intra coding

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Experimental Results

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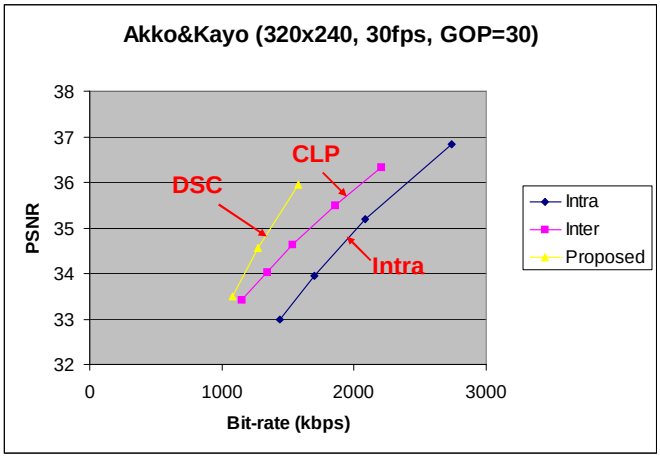

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Drifting Experiments

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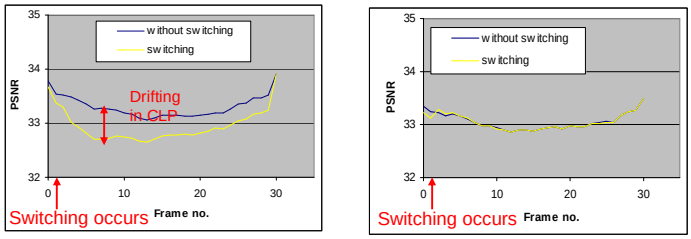
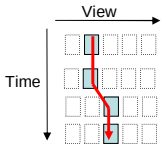
Our proposed algorithm is almost drift-free, since quantized coefficients in DSC coded MB are identically reconstructed

CLP DSC

Akko&Kayo (GOP=30)





View switching occurs at frame number 2

Scaling Experiments

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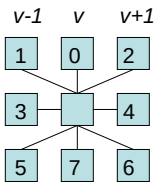
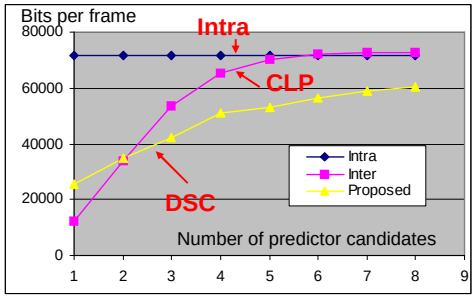
- Number of coded bits vs. number of predictor candidates





- Bit-rate of DSC-based approach increases at a slower rate compared with CLP
  - An additional candidate incurs more bits only if it has the worst correlation among all candidates

Conclusions

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- DSC-based multiview compression to address viewpoint switching
  - **Single** bitstream to support **multiple** decoding paths
  - Parity information **independent** of a specific predictor
  - Overhead depends on the **worst correlation** rather than the number of decoding paths
  - Outperform CLP and intra coding in terms of coding performance
  - Our proposed system is almost drift-free

Comments or Questions?

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Parity information is independent of a specific predictor

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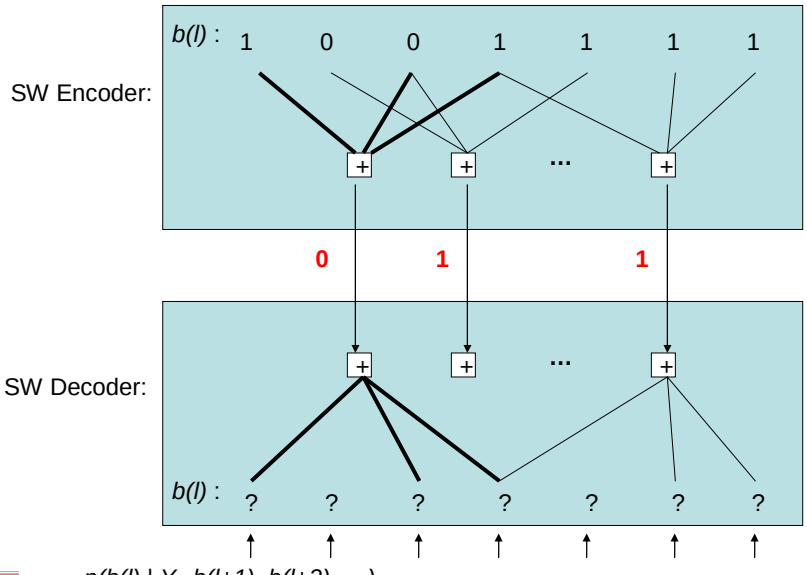

$p(b(l) \mid Y_i, b(l+1), b(l+2), \ldots)$

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