Logo Insertion into Compressed Video

EE Projects Contest 2006

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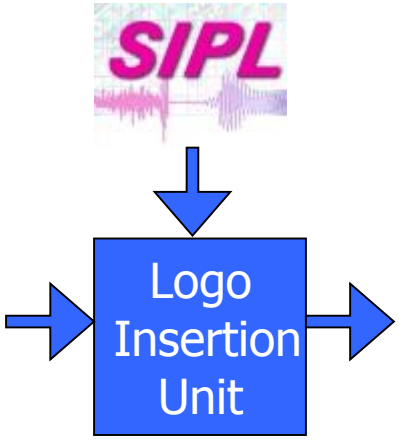
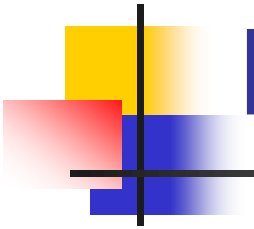
Supervisors: Naama Hait

Dror Porat

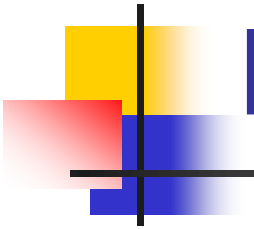
Logo Insertion





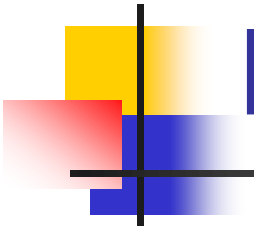
Motivation

- Naive solution available in market
- Critical problems
  - High computational complexity
  - Damage to Image quality
  - Expensive
- New solution is required!



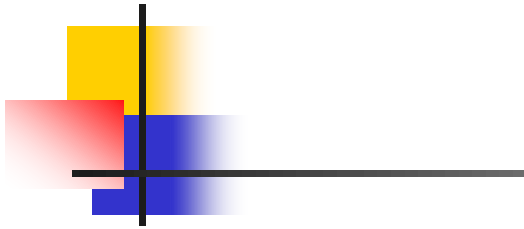
Project Objective

- Design and implementation of an efficient logo insertion system in the compressed domain



Presentation Layout

- Image and video compression fundamentals
- Logo insertion
- Further performance improvements
- Dynamic logo insertion (Video in Video)
- Conclusions

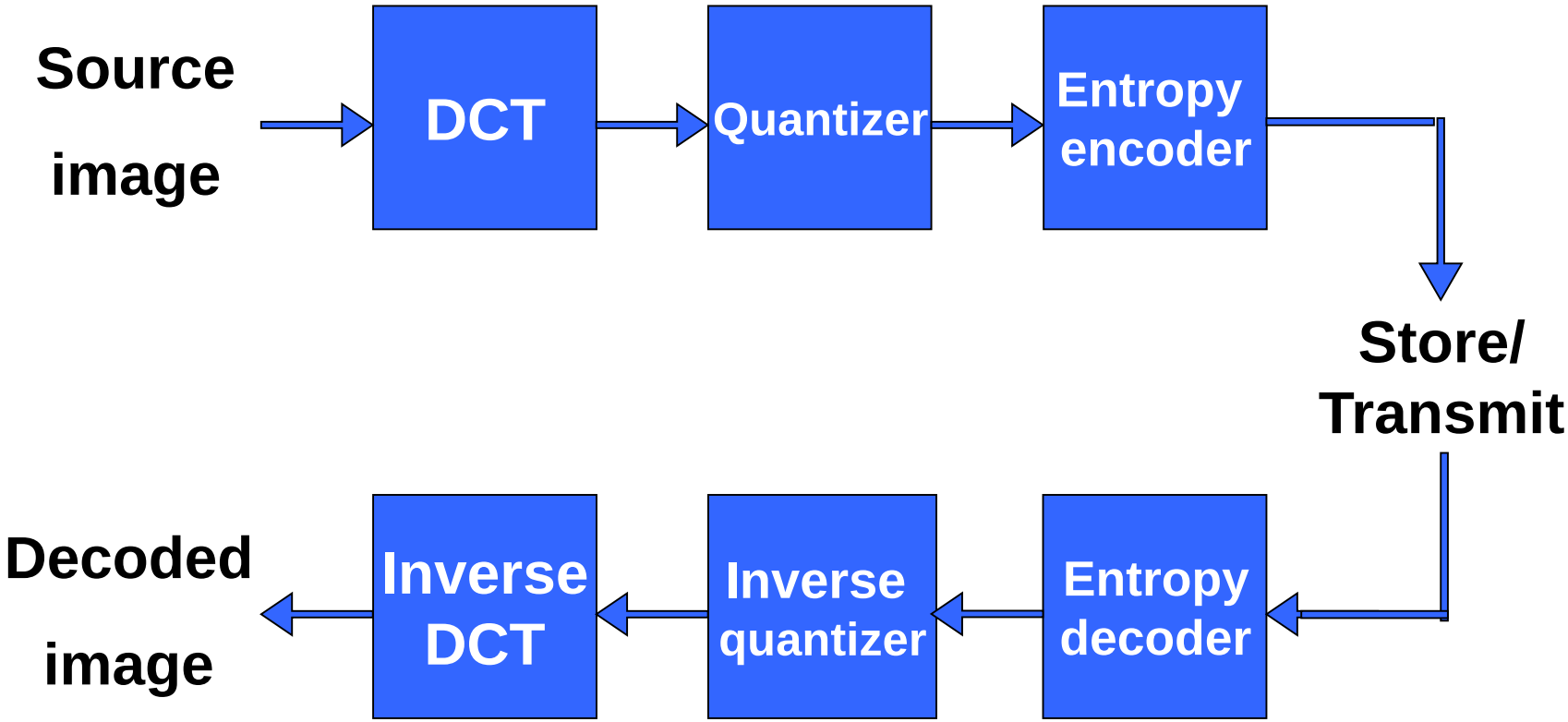


Introduction

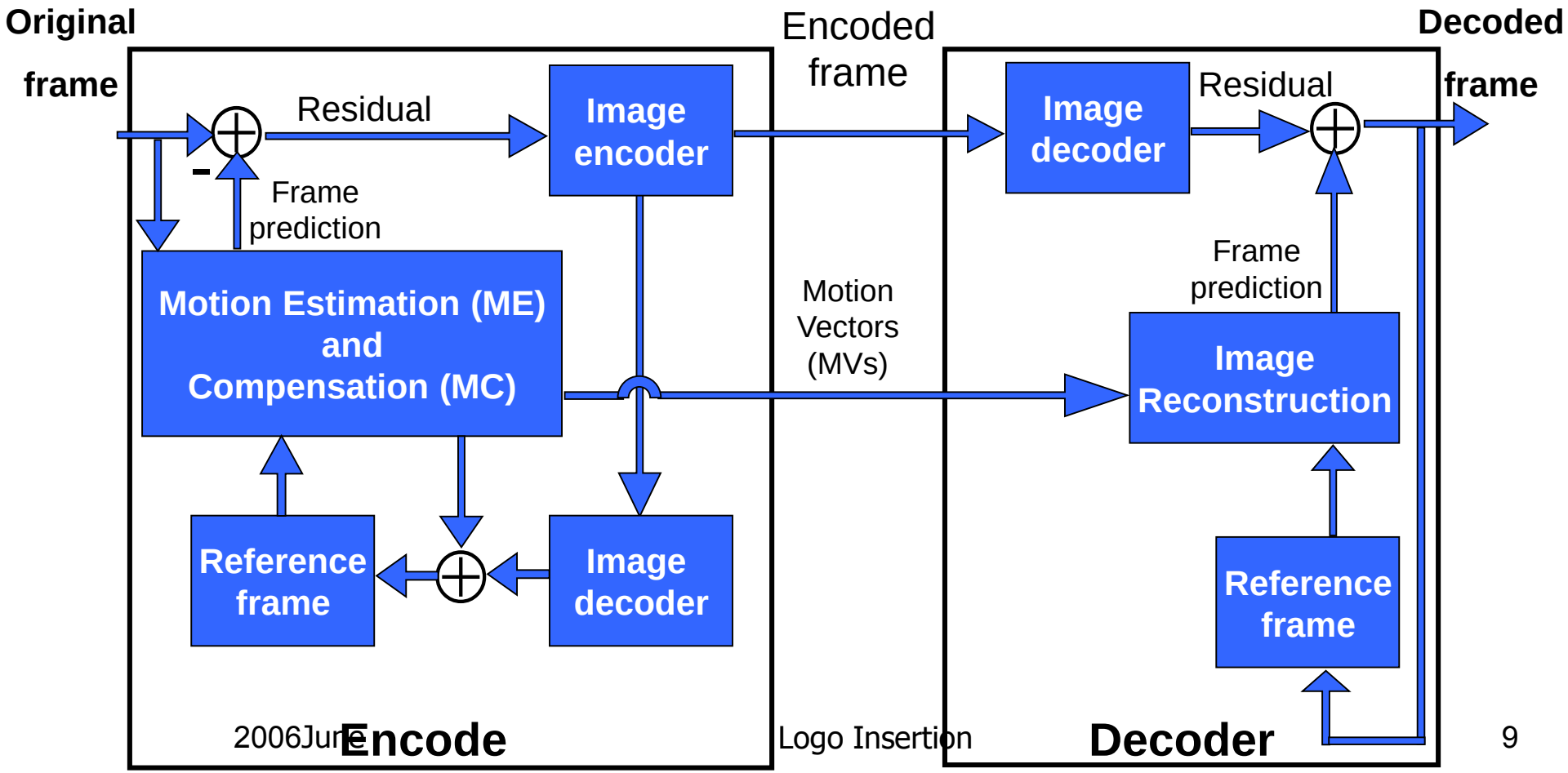
Image & Video Compression Fundamentals

- Redundancy in images & video signals:
  - Spatial redundancy
  - Subjective redundancy (sensitivity of the human visual system)
  - Statistical redundancy
  - Temporal redundancy (video)

Image CODEC


Source image
DCT
Quantizer
Entropy encoder
Store/ Transmit
Entropy decoder
Inverse quantizer
Inverse DCT
Decoded image

Video CODEC


Original
frame
Residual
Image
encoder
Encoded
frame
Image
decoder
Residual
Decoded
frame
-
Frame
prediction
Motion Estimation (ME)
and
Compensation (MC)
Motion
Vectors
(MVs)
Frame
prediction
Image
Reconstruction
Reference
frame
Image
decoder
Reference
frame
Encode
Decoder

Motion Compensation (MC)

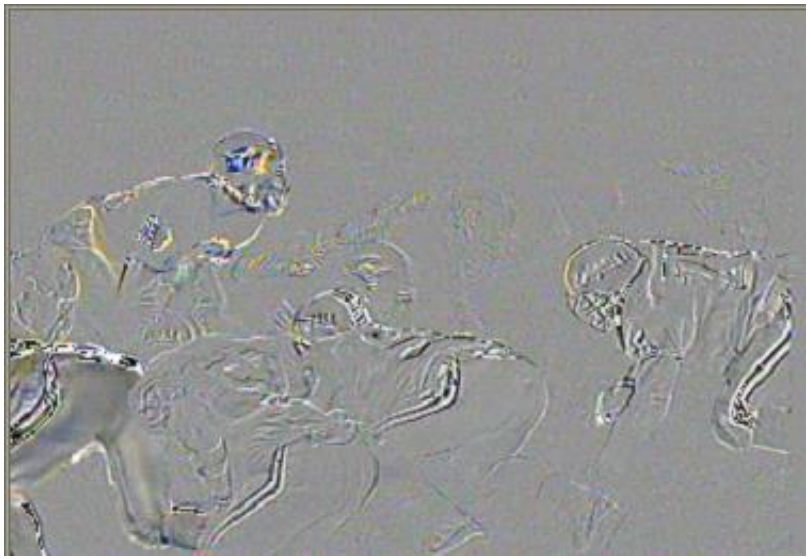
Frame

Previous frame

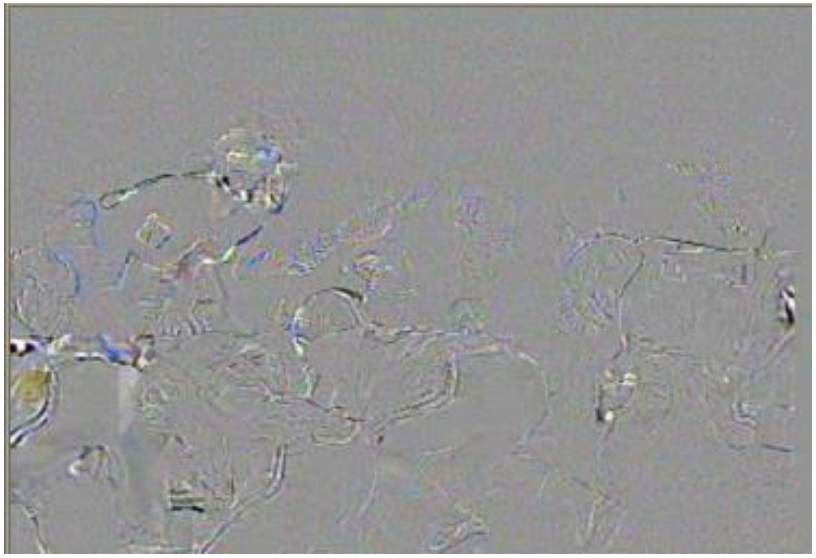
Prediction

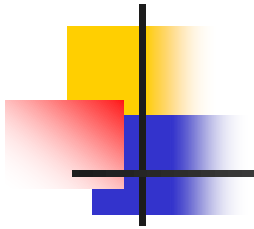
Motion Compensation (MC) (cont.)

Differences from previous frame



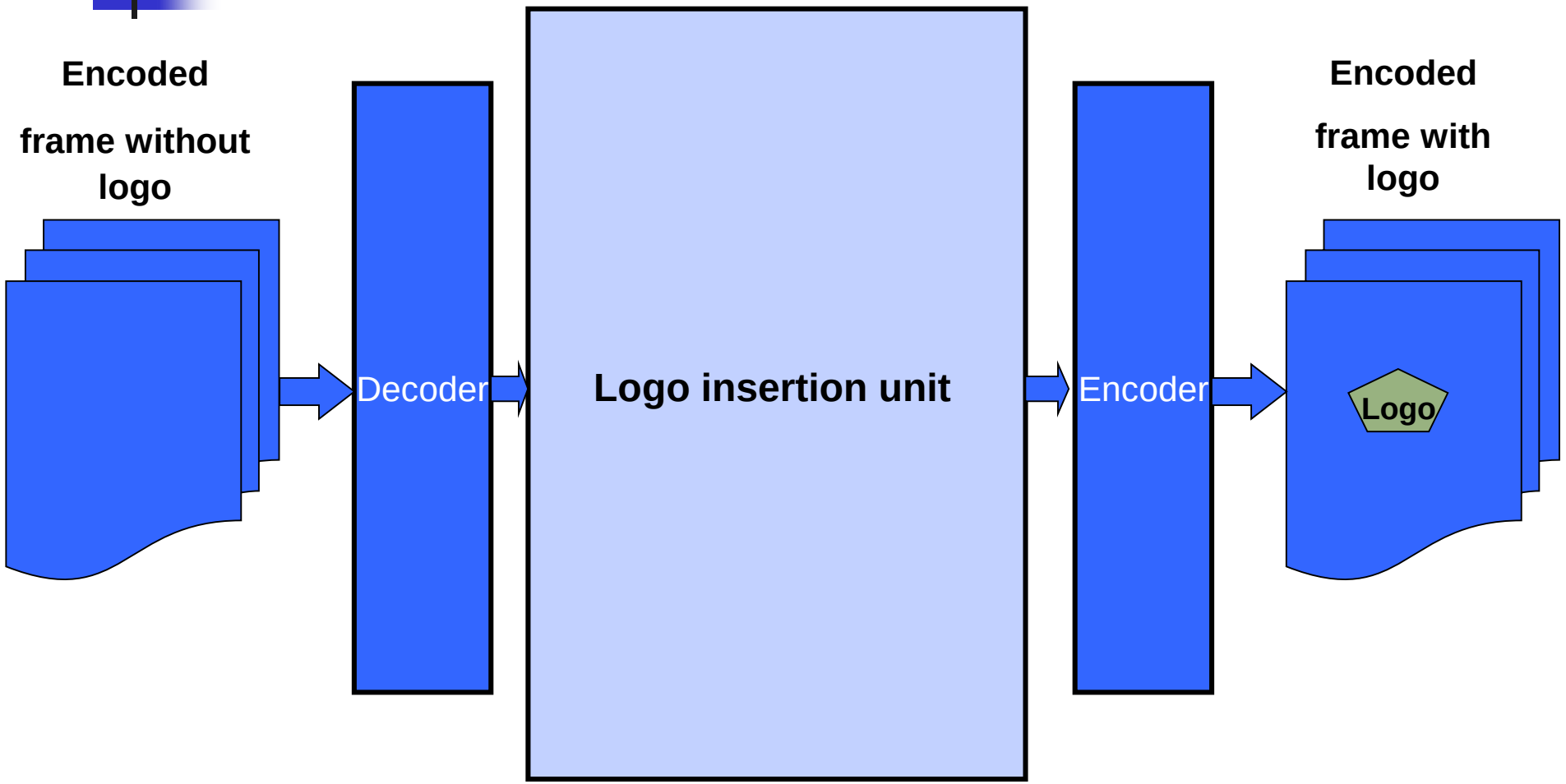
Differences from prediction



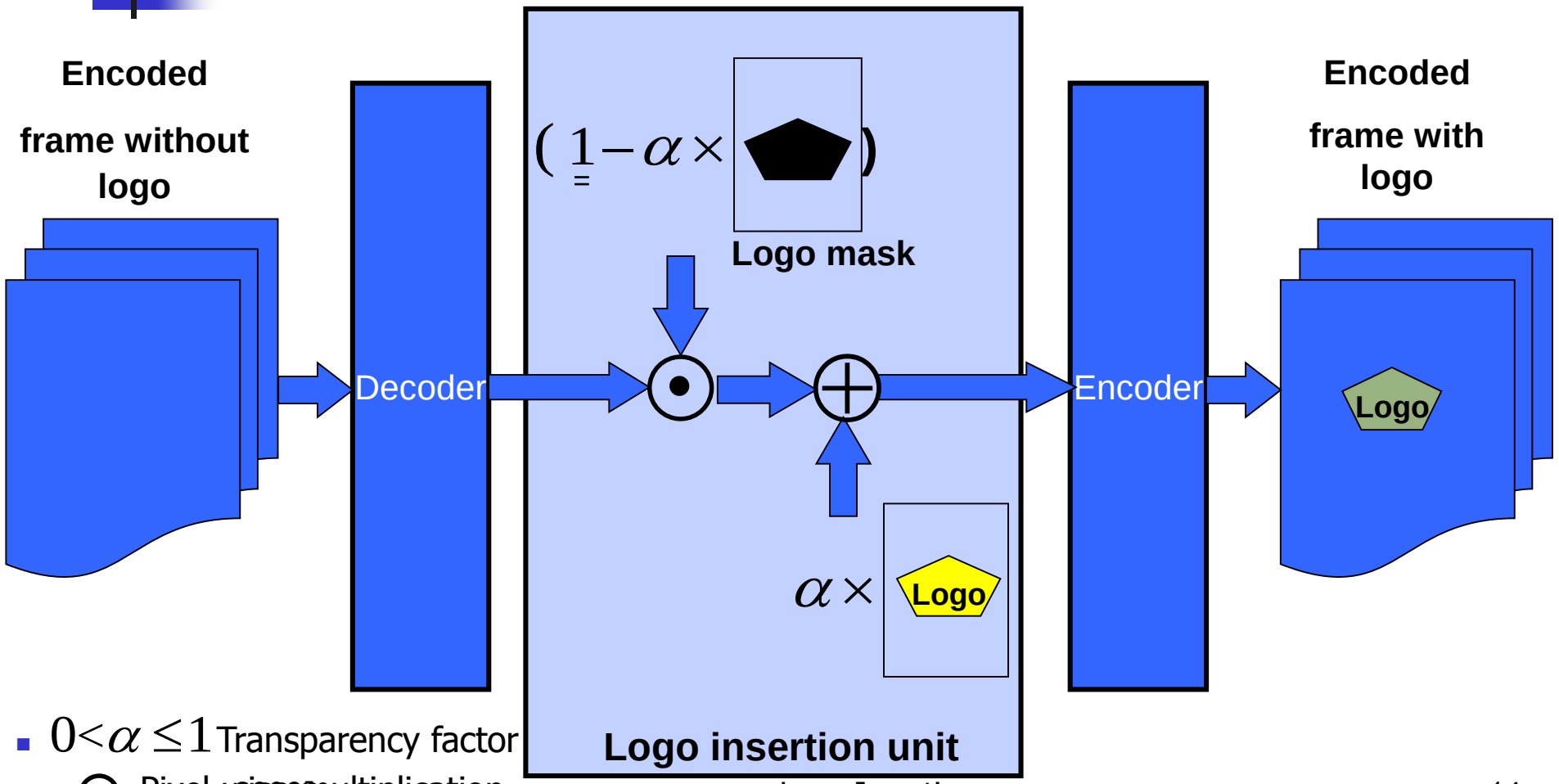


Logo Insertion

Logo Insertion - Naive Solution

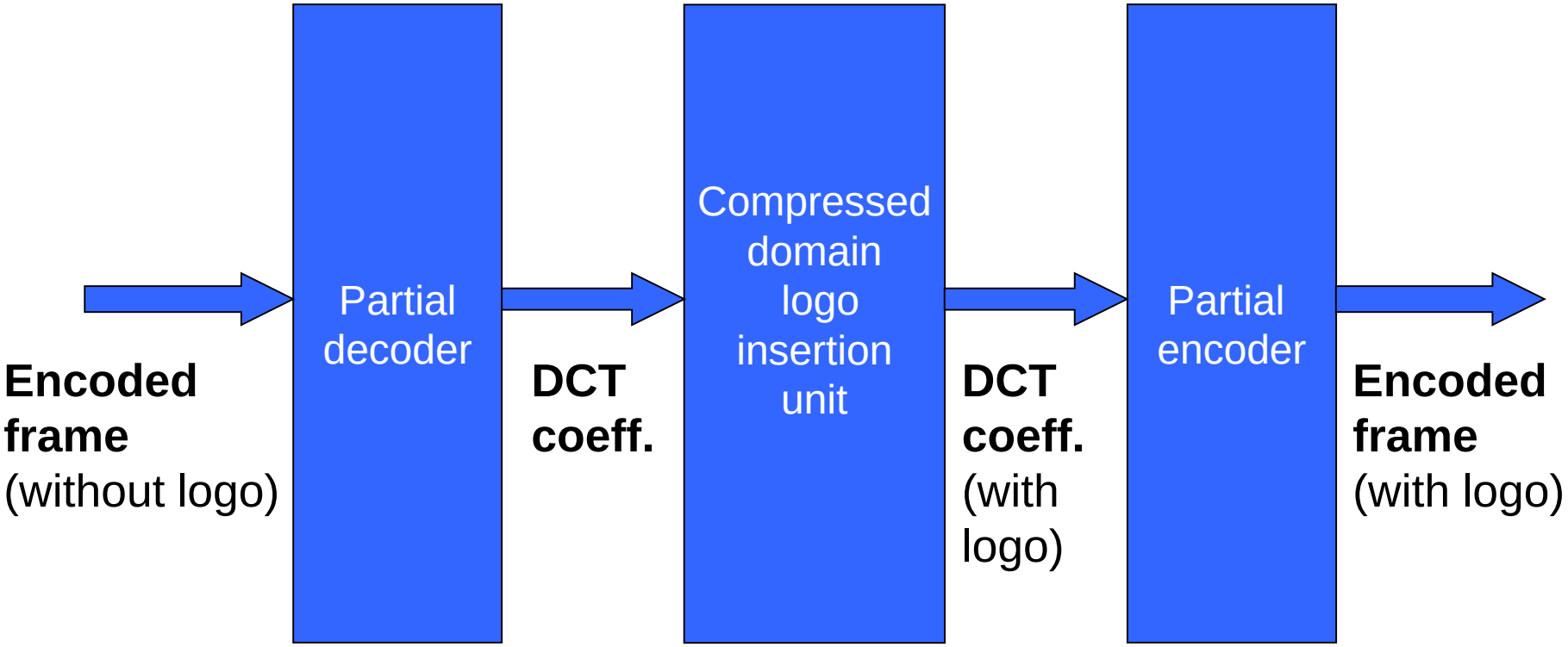


Logo Insertion - Naive Solution

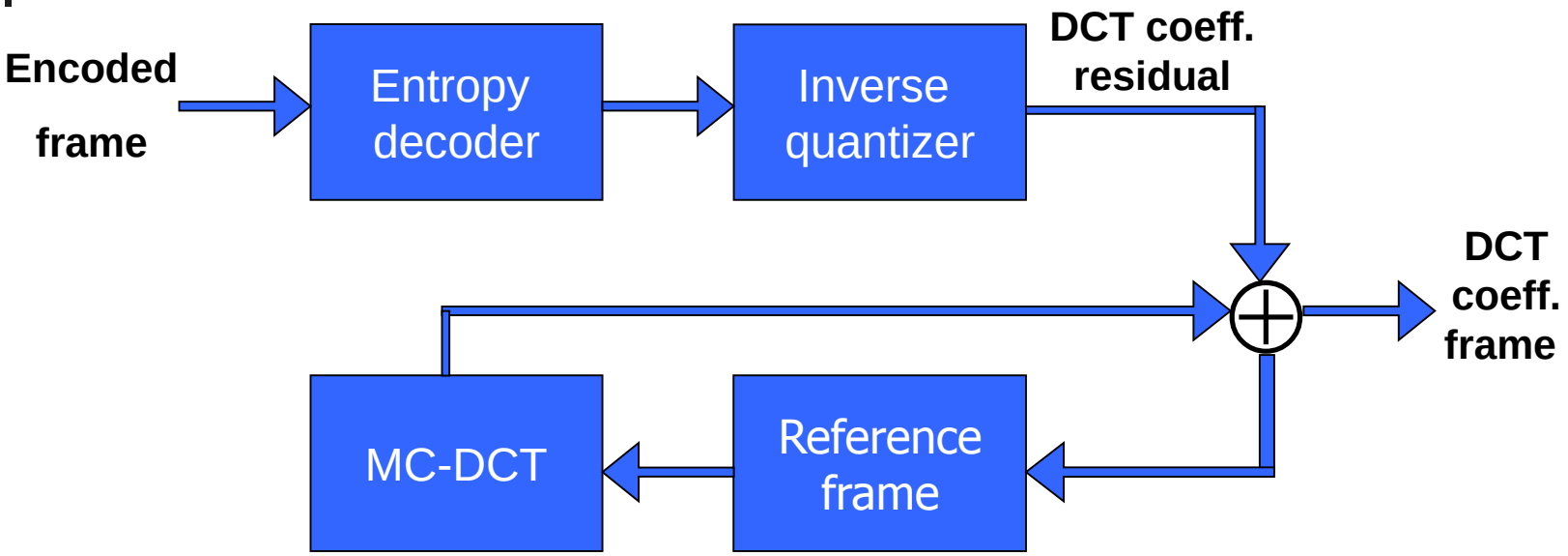


- $0<\alpha\leq 1$ Transparency factor
- $\odot$ Pixel-wise multiplication

Compressed Domain Logo Insertion



Partial Decoding



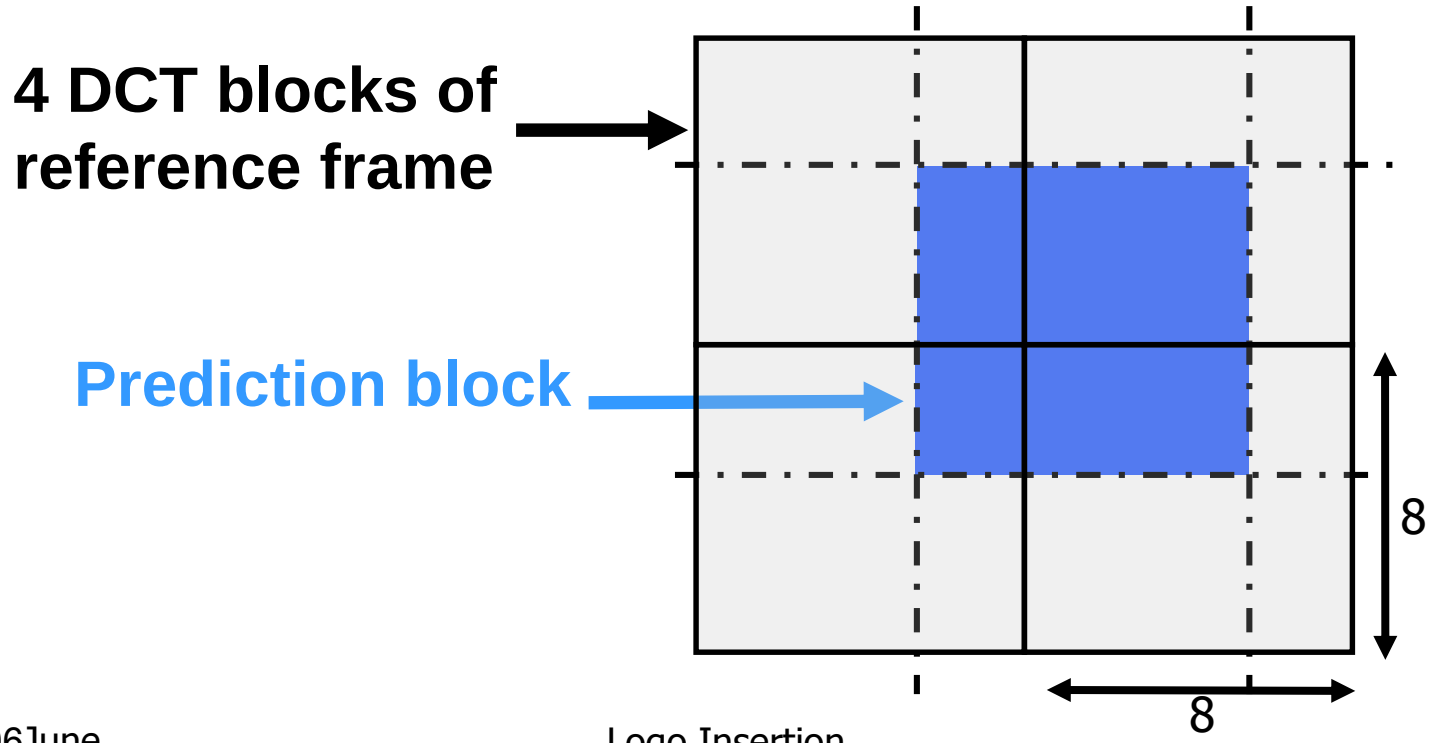
MC-DCT: Motion compensation in compressed domain

Reference: [1] N. Merhav, V. Bhaskaran, A fast algorithm for DCT-domain inverse motion compensation, Proceeding of ICASSP (May 1996), Atlanta, GA, 2307-2310.

[2] Shih-Fu Chang and David G. Messerschmitt, “Manipulation and Compositing of MC-DCT Compressed Video” IEEE Journal of Selected Areas in Communications, vol. 13, no. 1, pp. 1–11, 1995.

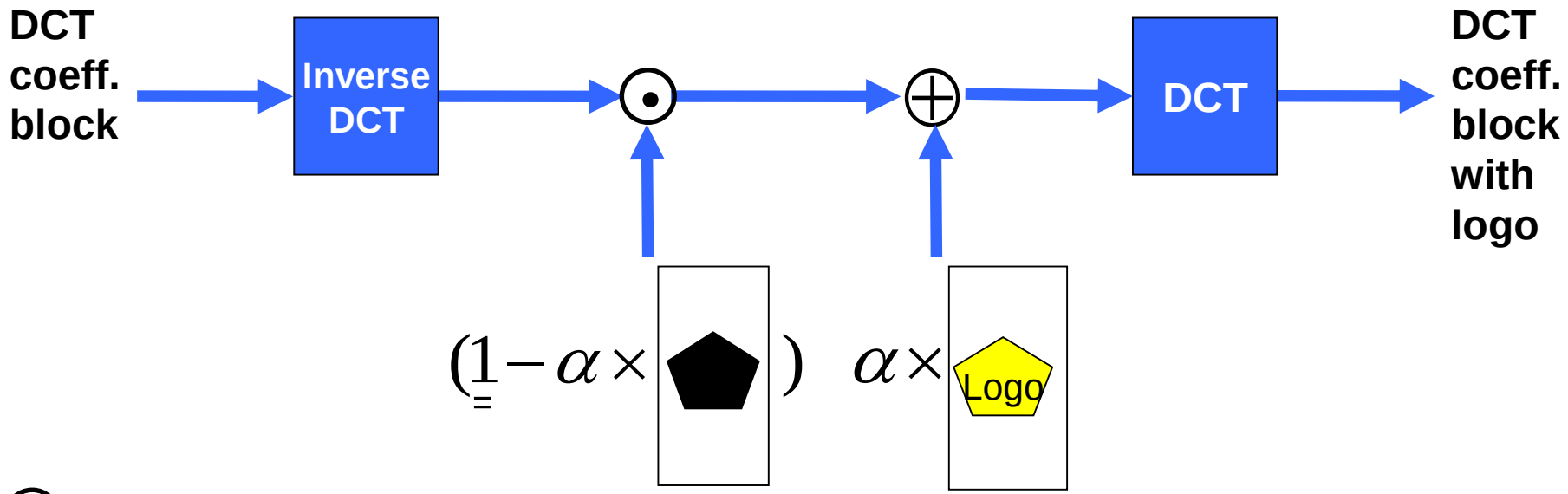
Motion Compensation in Compressed Domain (MC-DCT)

Prediction DCT coeff. block is obtained from up to 4 adjacent blocks of the reference frame



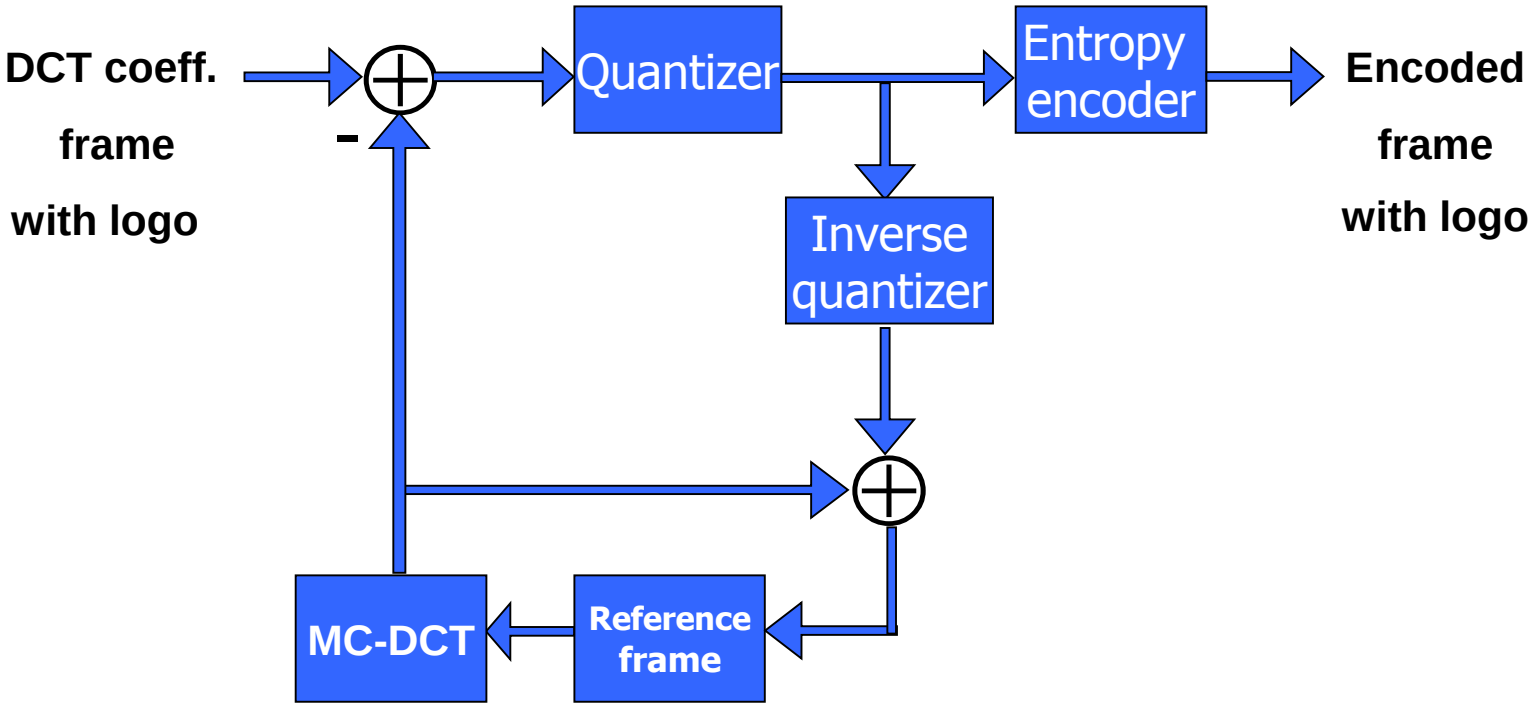
Compressed Domain Logo Insertion Unit

Performed on blocks in logo region only



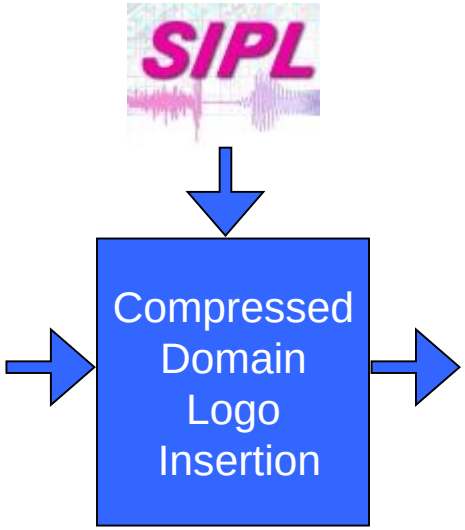
⊙ Pixel-wise multiplication

Partial Encoder



MC-DCT Motion compensation in compressed domain

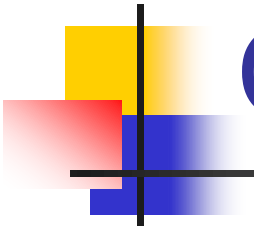
Compressed Domain Logo Insertion



Further Performance Improvements

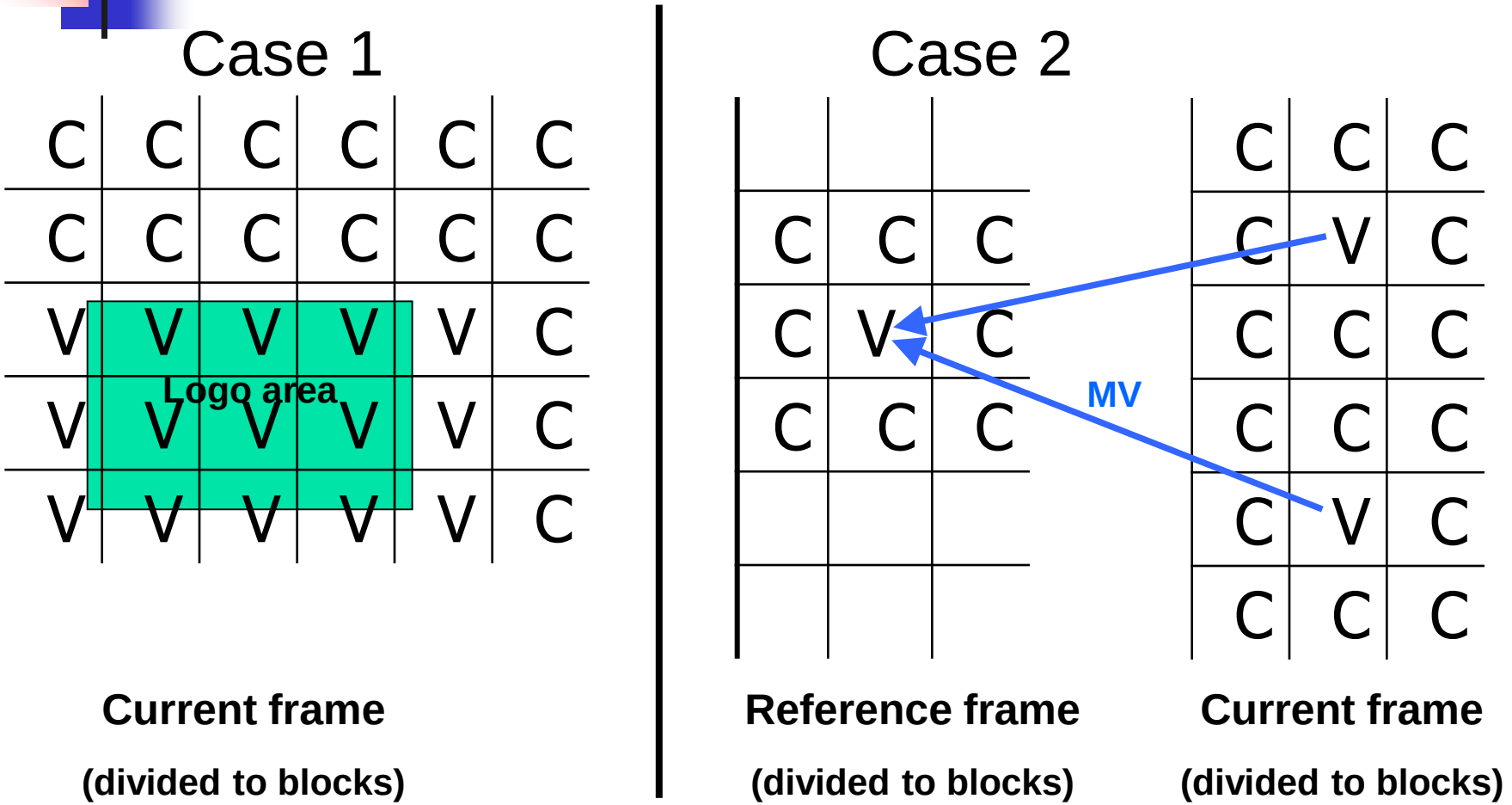
- Goals
  1. Reduce computational complexity
  2. Improve image quality for a given bit rate
  3. Control output bit rate

1. Reduce Computational Complexity



- A typical logo is up to 10% of the image size in a video
- Most of the image is not changed by the logo insertion
- How can we save computations?

‘Constant’ Blocks and ‘Variable’ Blocks



‘Constant’ Blocks and ‘Variable’ Blocks (cont.)

Example: - 'constant’ and ‘variable’ blocks map

White – ‘variable’ blocks

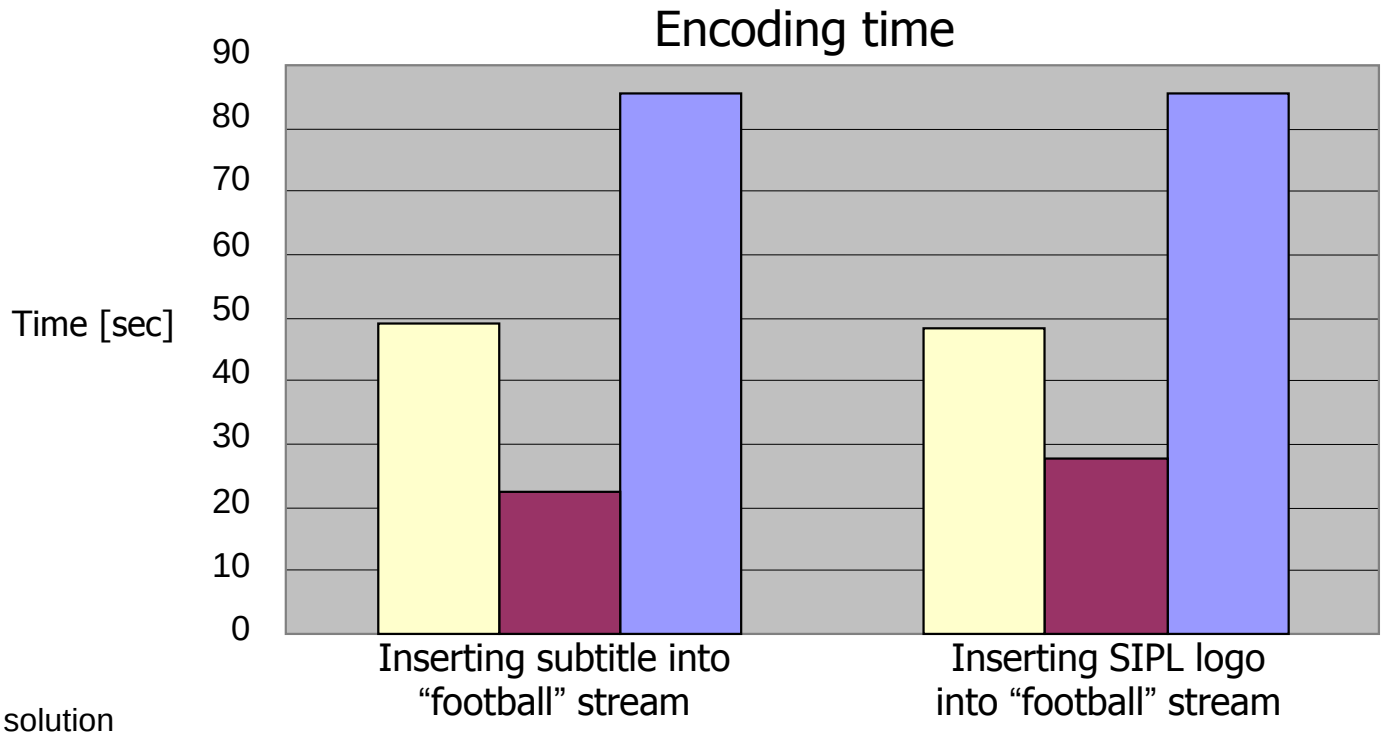
Black – ‘Constant’ blocks

Compressed Domain Logo Insertion

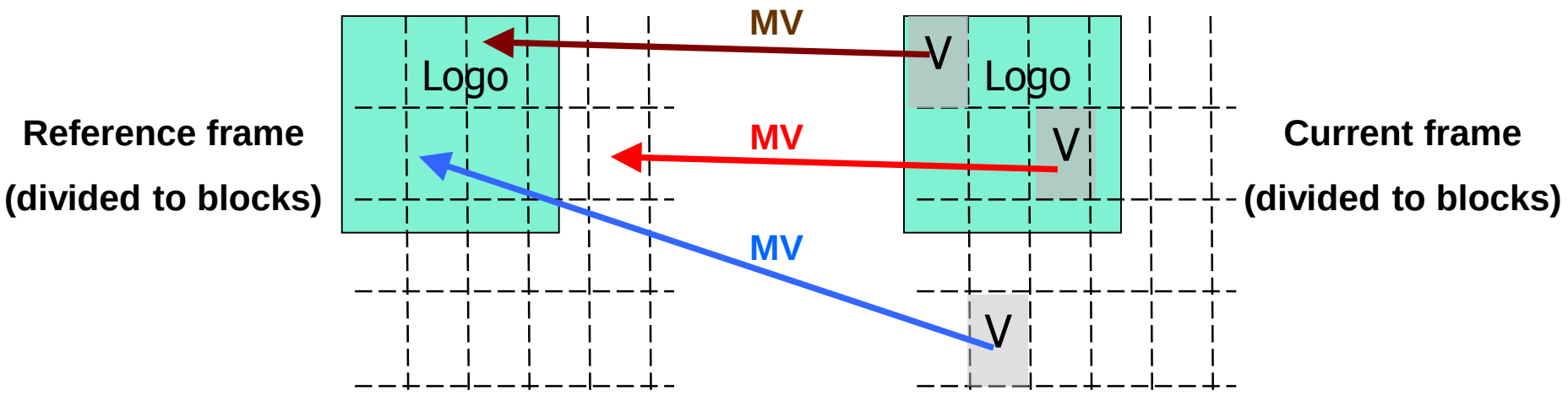
- System parameters
  - Pentium 4, 3GHz
- Streams parameters
  - Resolution 352X240 pixels
  - 150 frames
  - Bit rate 2MBit/sec or 4MBit/sec

‘Constant’ Blocks and ‘Variable’ Blocks (cont.)

- Computational complexity of partial encoder is reduced by 70%
- Compressed domain encoding saves 30-70% of encoding computations



2. Improve Image Quality for a Given Bit Rate

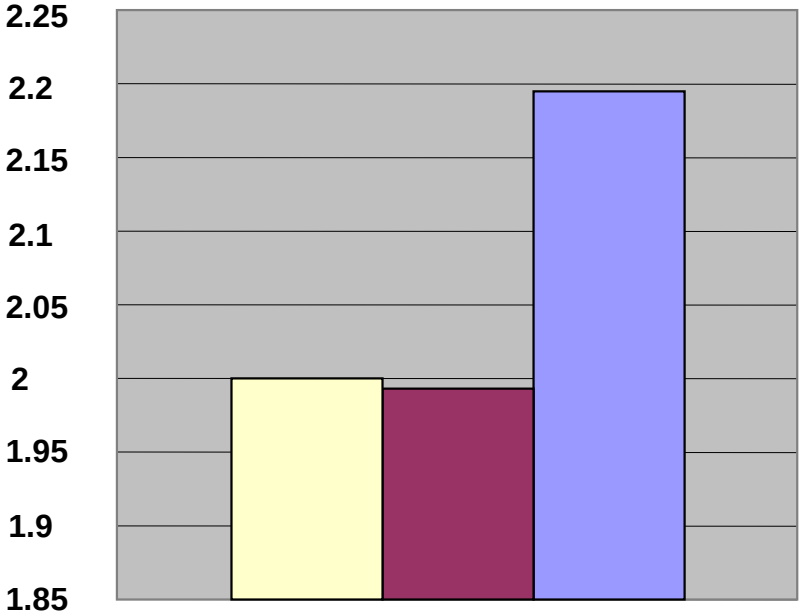


- Step 1 – calculate error with zero motion vector
- Step 2 – compare to current error
- Step 3 – zero motion vector if the error reduced

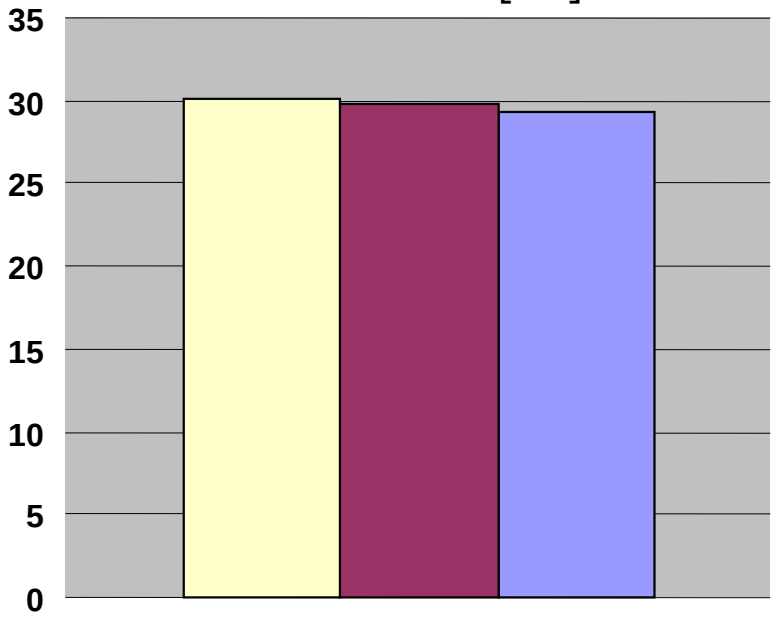
Zero Motion Vectors

- Bit rate reduced while PSNR is the same
- Time complexity is not affected

Bit rate $\left[\frac{Mbit}{\sec}\right]$



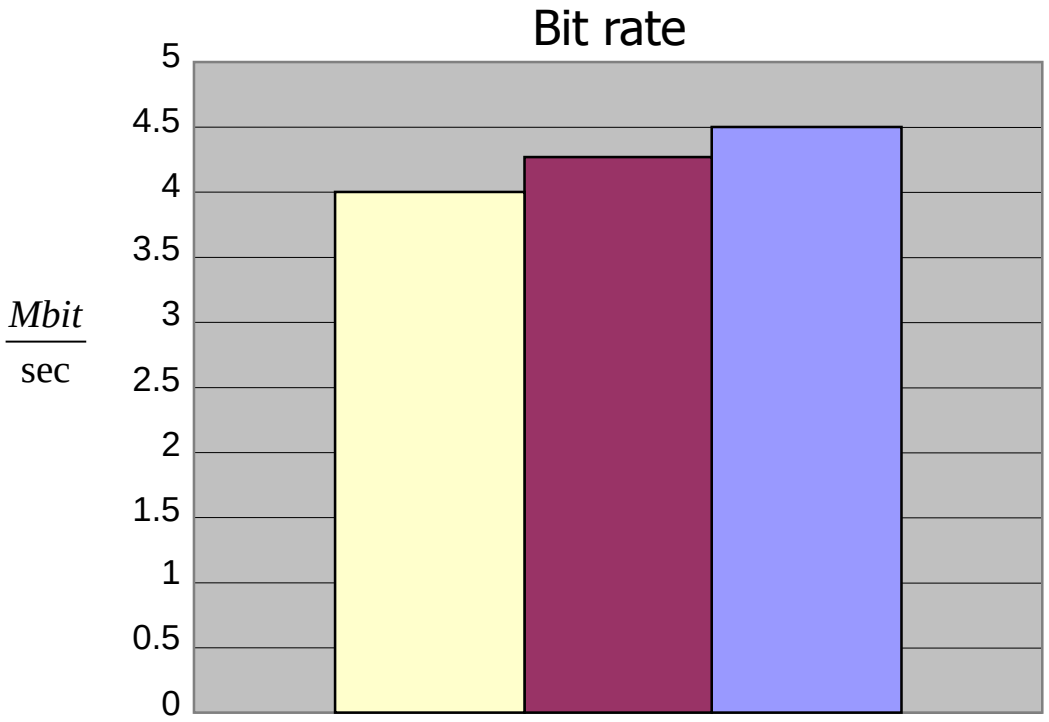
PSNR $[dB]$



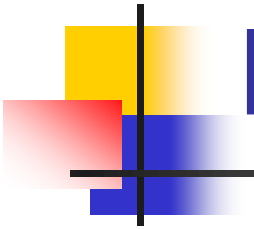
- Input stream – “football” 2Mbit/sec
- Output with zero motion vectors (“football” with SIPL logo)
- Output without zero motion vectors (“football” with SIPL logo)

3. Control Output Bit Rate

- **Problem:** bit rate is significantly changed



- Input stream – “flower garden” 4Mbit/sec
- Output with zero motion vectors (“flower garden” with subtitle logo)
- Output without zero motion vectors (“flower garden” with subtitle logo)

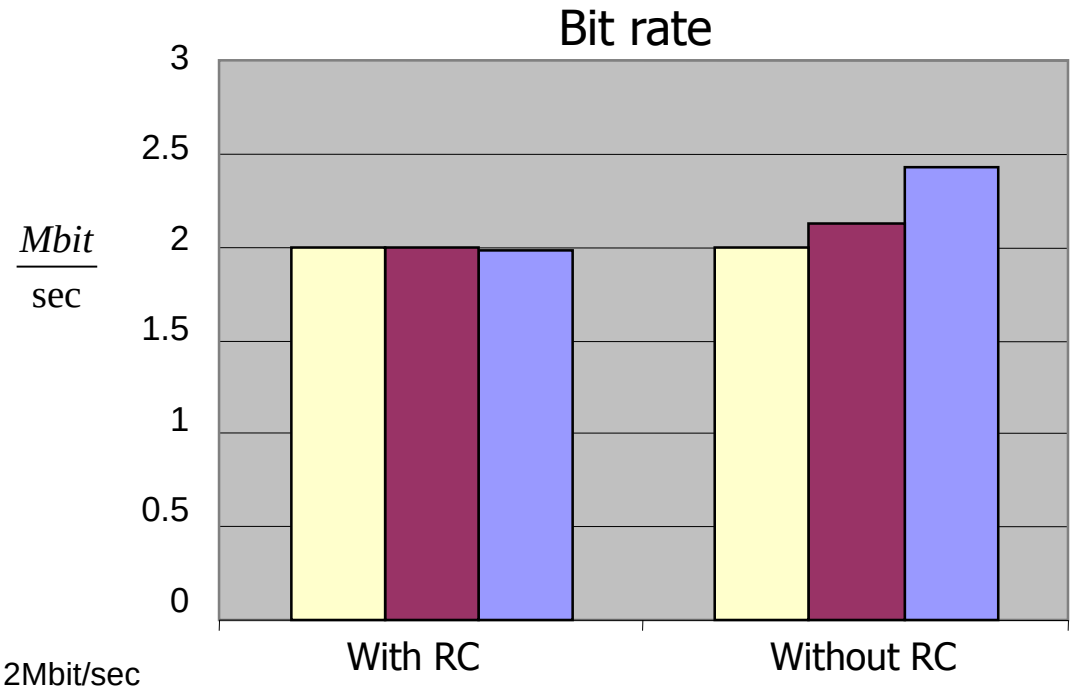


Rate Control

- MPEG2-TM5 rate-control algorithm
  - Estimates complexity of current frame using complexity of previous frame of the same type
  - Determines quantization level
  - Produce target bit rate

Rate Control (cont.)

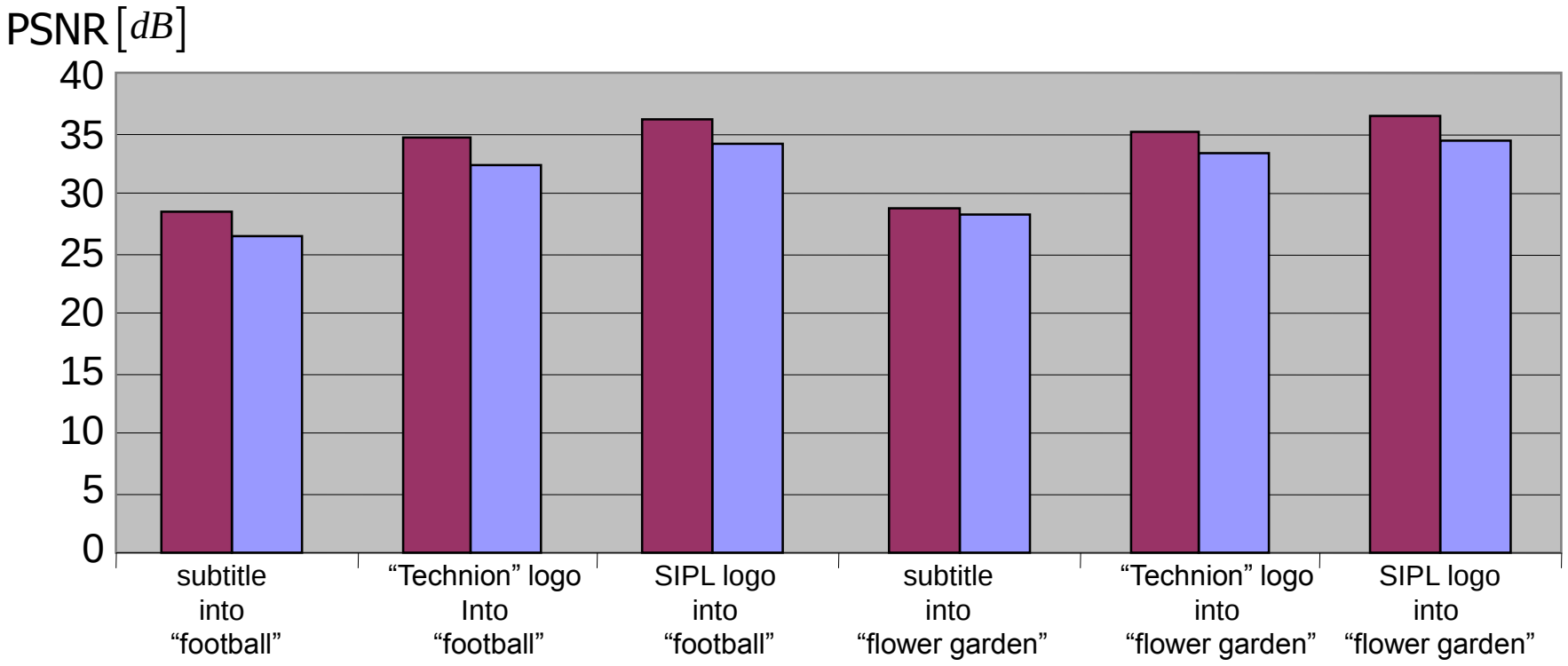
- Bit rate maintained

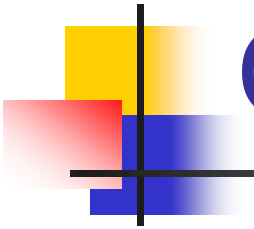


- Input stream – “football” 2Mbit/sec
- Output with zero motion vectors (“football” with subtitle logo)
- Output without zero motion vectors (“football” with subtitle logo)

Zero Motion Vectors with Rate Control

- Zero motion vectors improves the PSNR, rate control keeps the rate
- PSNR in logo region increased, PSNR of image slightly changes



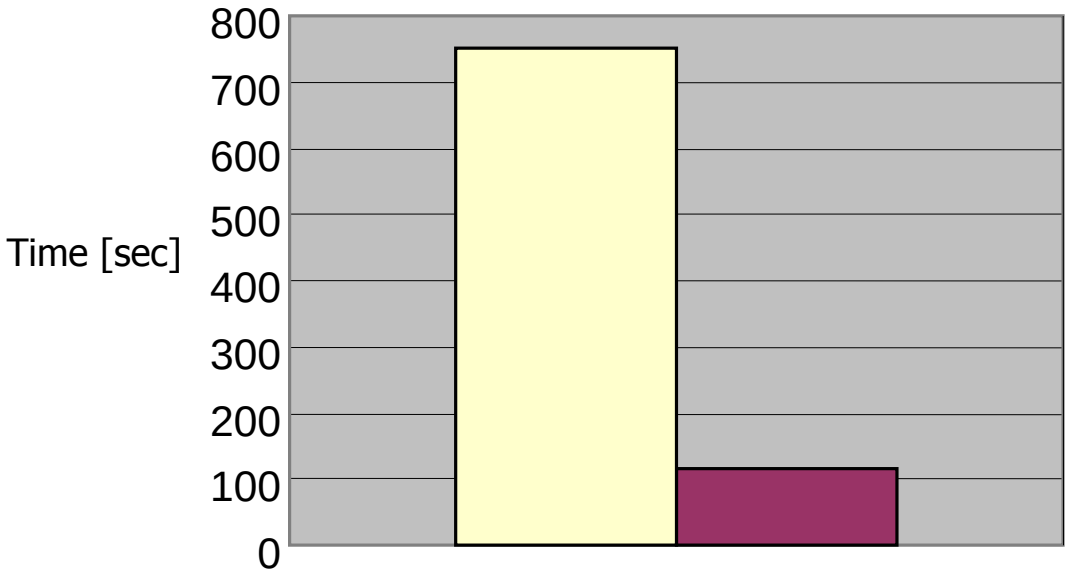


Conclusions

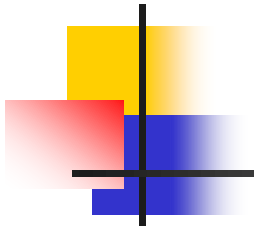
- ‘Constant’ and ‘variable’ blocks mapping significantly reduces computational complexity
- Rate control is necessary for maintaining bit rate
- Selectively resetting motion vectors improves PSNR

Overall Run Time

- Run time reduced by 80%

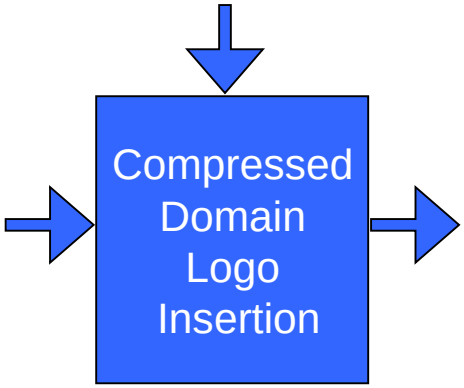


- Naive solution
- Compressed domain with zero motion vectors and RC (“football” with subtitle logo)



Dynamic Logo (Video in Video)

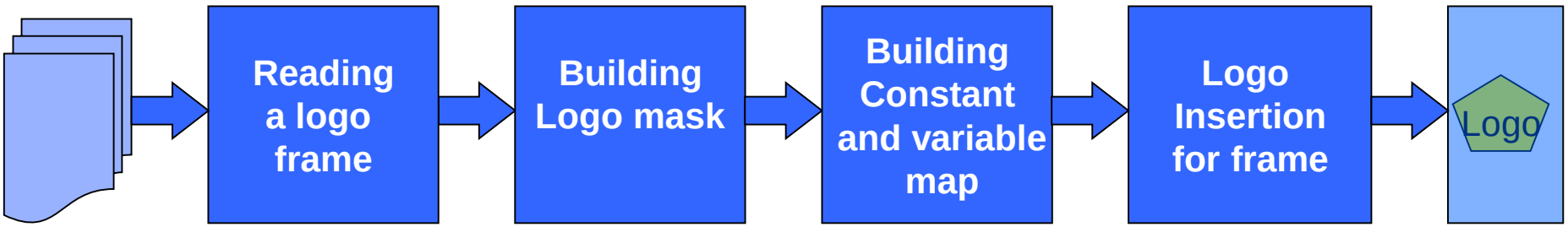
Dynamic Logo Insertion



Dynamic Logo Insertion (cont.)

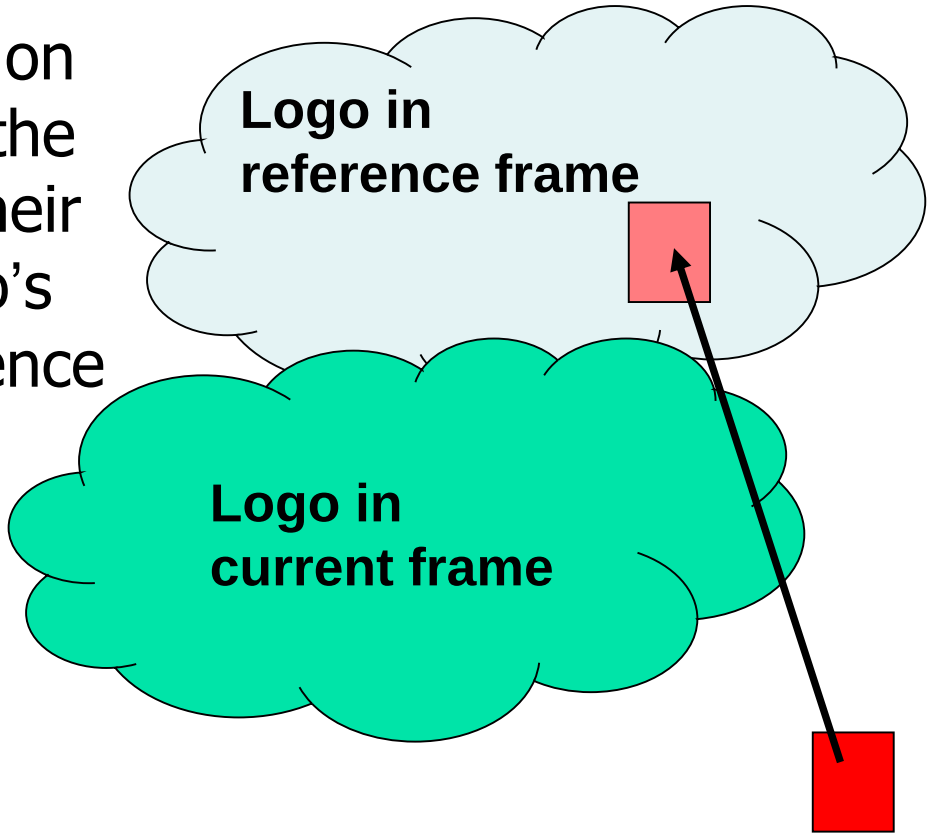
- Assumption: dynamic logo input is not compressed
- Each ‘constant’/’variable’ map is built from the mask of the current logo frame and the maps of its reference frames

Insertion unit for dynamic logo:

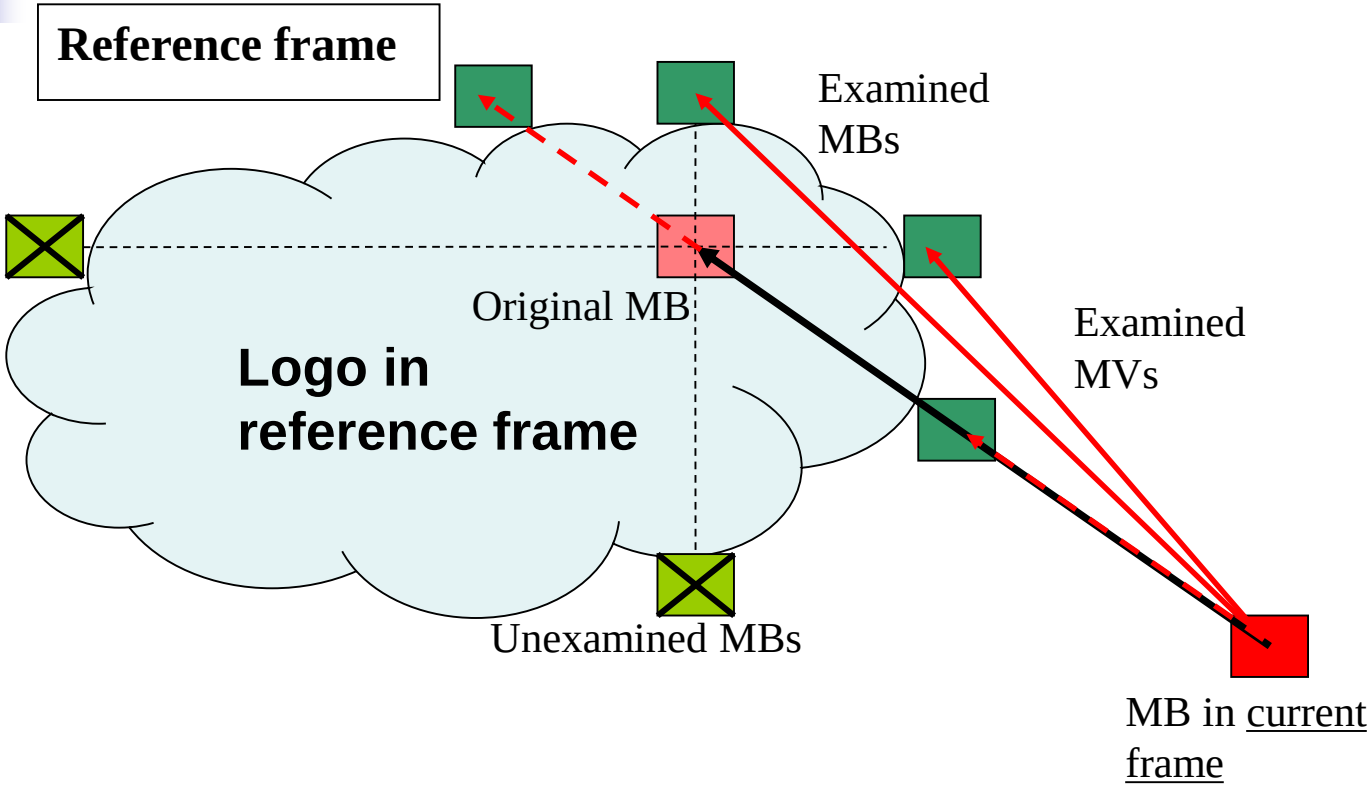


Changing Motion Vectors

- MVs change is made on MBs that are not on the logo's support, but their MV points to the logo's support on the reference frame.

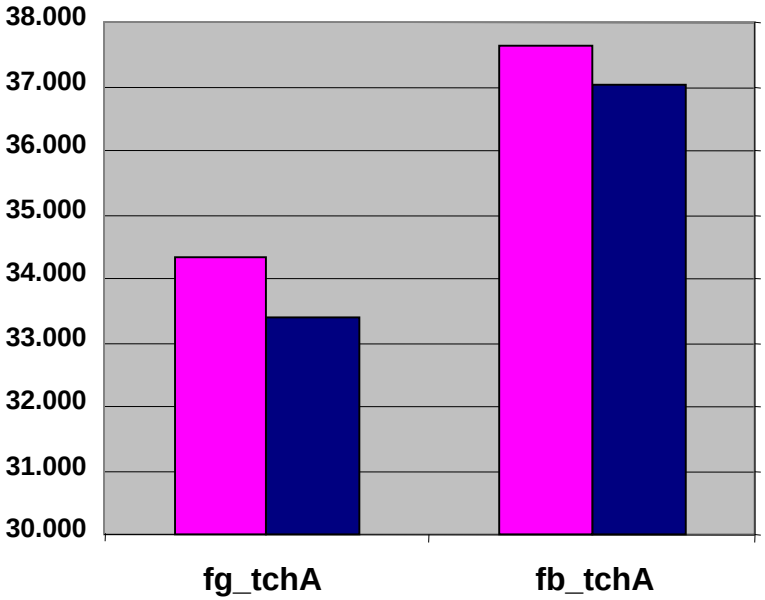


Changing Motion Vectors (cont.)

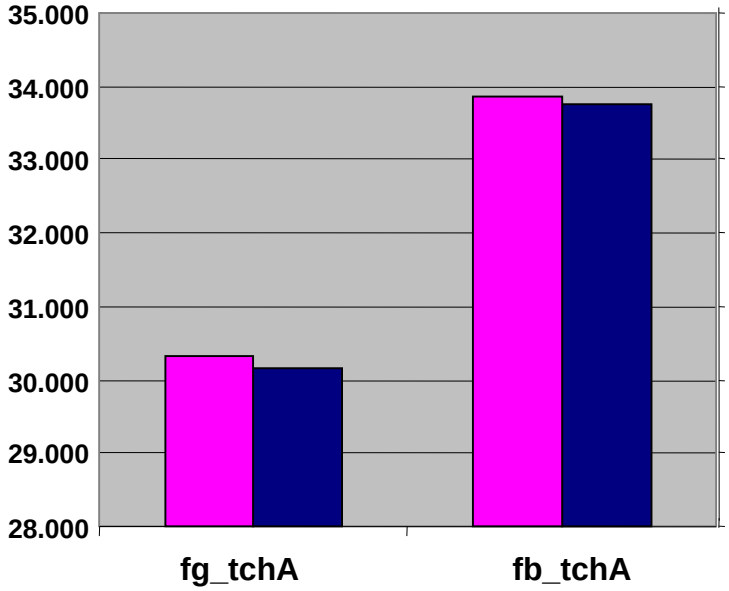


Changing Motion Vectors (cont.)

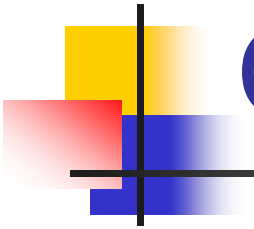
PSNR IN LOGO AREA $[dB]$



PSNR OUT LOGO AREA $[dB]$



- COMPRESSED DOMAIN WITHOUT CHANGING MVs
- COMPRESSED DOMAIN WITH CHANGING MVs



Conclusions

- Fast and effective logo insertion solution
- Compressed domain advantage
- Unique solution for market needs