Simulink Based Architecture Prototyping of Compressed Domain MPEG-4 Watermarking

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Outline of the Talk

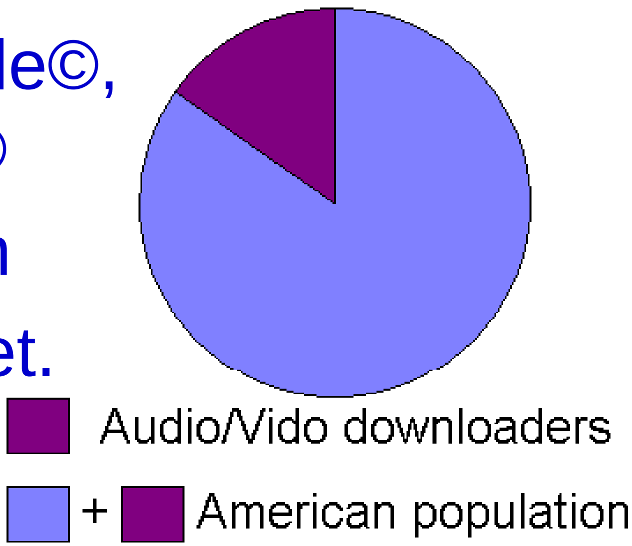
- Introduction
- Related Prior Research
- Proposed Watermarking Algorithm
- Proposed Watermarking Architecture
- Simulink Prototyping
- Experimental Results
- Conclusions

Introduction

Trends of Online Multimedia

Facts of Multimedia Streaming over Internet

- Millions of users download audio/videos.
- Audio/video ISP: Amazon©, AOL©, Apple©, Google©, MSN©, Yahoo©, and Youtube©
- HDTV, Video On Demands services soon
- Cost-free duplicating/distributing in Internet.
- Abuse Copyrights in the Internet



Copyright and Intellect Property Protection

- Against pirate duplicating and distribution
- Against unauthorized modifications
- Arbitrate ownership disputes

Watermarking: Copyright Solution

Video Copyright Protection: *Watermark* **(text, logo, animation)**

- Perception
  - Visible
  - Invisible
- Strength
  - Robust
  - Fragile
- Domain
  - Spatial
  - Frequency (DFT, DCT, DWT)

Offline solution is acceptable.

Internet Protocol Television (IP-TV): Broadcasting

Different Networks:

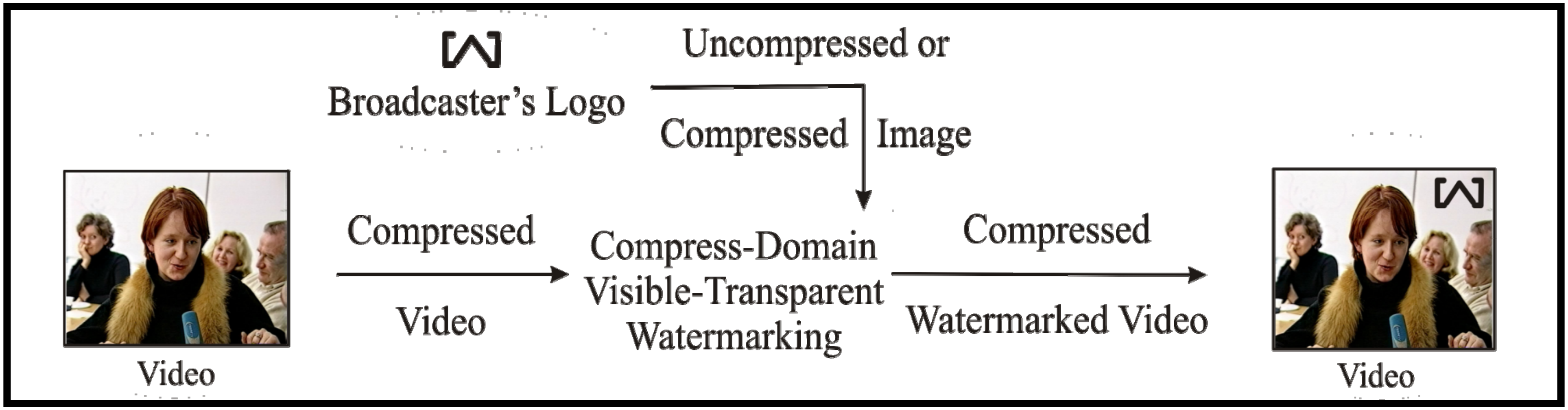
Network	Bit rate
ADSL/Cable Modem	2/30Mbps
Ethernet/Fast Ethernet	10/100/1000 Mbps
NTSC video broadcasting (raw)	216 Mbps
HDTV video broadcasting (raw)	1.3Gbps

Video Compression Standards:

- H.261, H.263, H.264 from ITU;
- MPEG-1(VCD), MPEG-2(DVD), MPEG-4 from MPEG of ISO

Compression Rate > **100:1**

Real-Time Watermarking: IP-TV



- **Situation**: Video residing in a server to be broadcasted by different stations under different broadcasting rights.
- Real-time insertion of broadcasters logon in compressed video is necessary.

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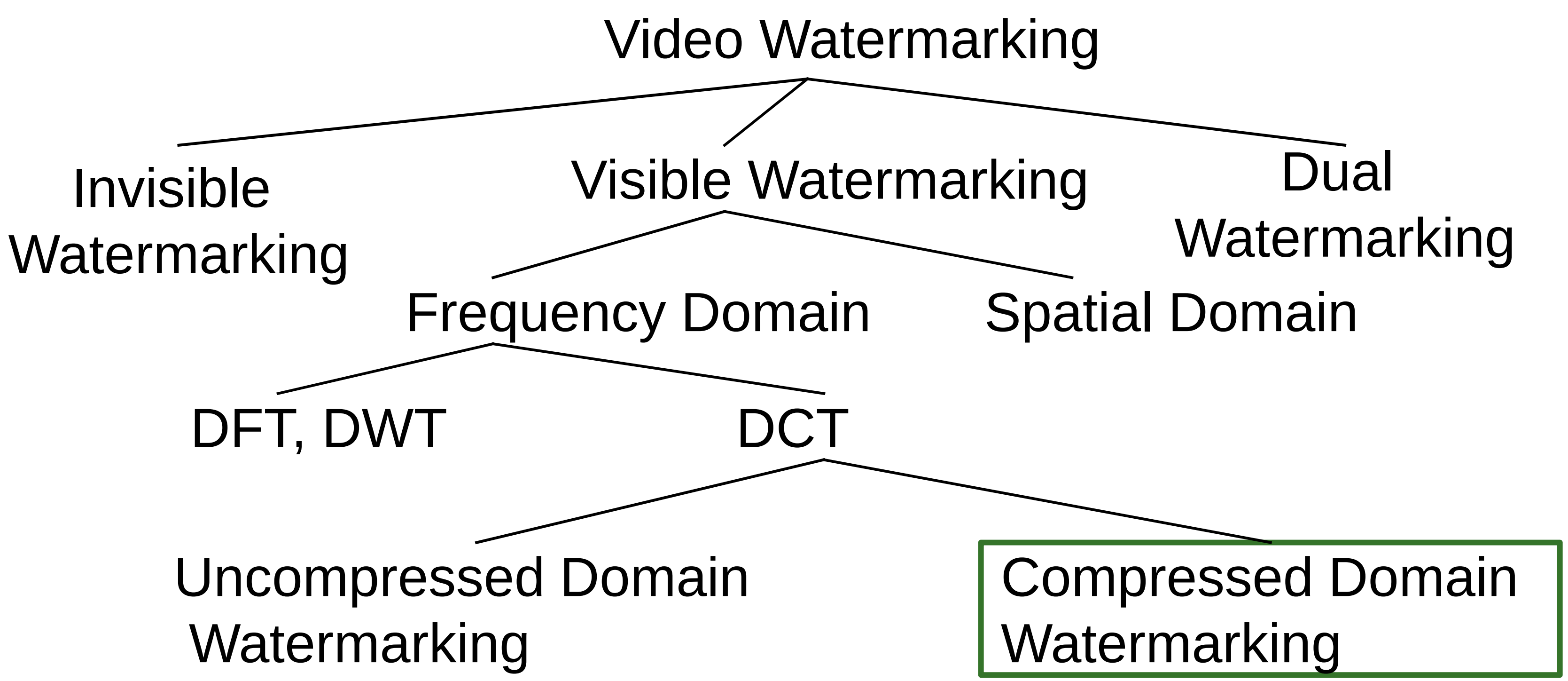
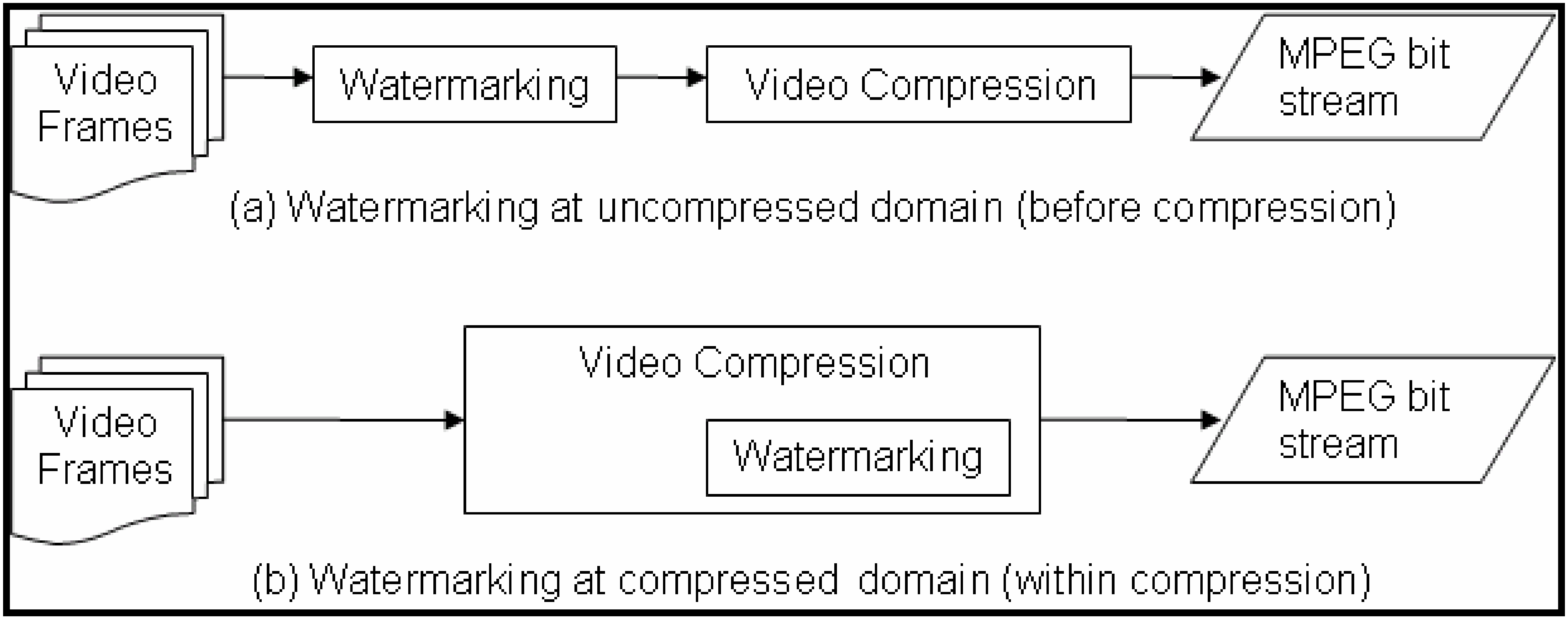
Video Watermarking : Types …



Video Watermarking : Types



Contributions of This Paper

- A compressed domain perceptual based adaptive visible watermarking algorithm suitable for video broadcasting.
- Application specific architectures for real-time watermarking in the context of compressed video (MPEG-4).
- Simulink prototyping of the proposed architectures which can be integrated in multimedia producing appliances (e.g. digital camera, network processor).

Related Prior Research

Watermarking Architectures …

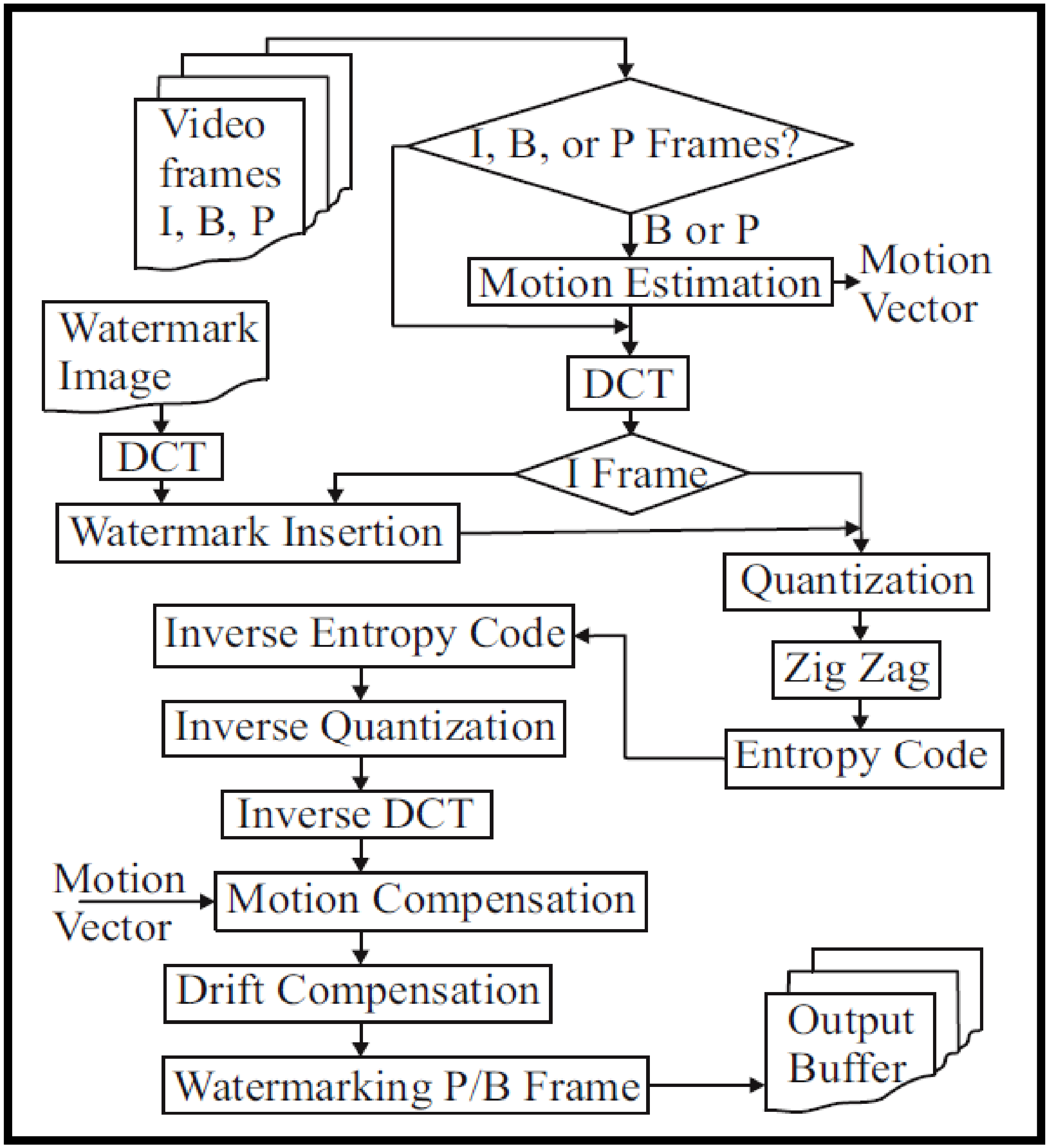
- **Mathai 2003**: A spatial domain real-time watermarking architecture for broadcasting.
- **Tsai 2003**: A DCT domain invisible watermarking configurable architecture.
- **Garimella 2003**: A spatial-domain invisible-fragile watermarking architecture.

Watermarking Architectures

- **Mohanty 2005**: A hardware architecture that can insert two visible watermarks in images in the spatial domain is introduced. (Concept of Secure Digital Camera is introduced.)
- **Fan 2005**: An adaptive DWT (discrete wavelet transform) based visible watermarking architecture is proposed.
- **Mohanty 2009**: An uncompressed domain visible watermarking architecture and FPGA prototyping is proposed.

Proposed Watermarking Algorithm

Compressed Domain Algorithm: Flow



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Compressed Domain Algorithm: Issue

For compressed domain video watermarking, drifting is an issue.

Video Watermarking Algorithm : The Challenges

- Selection of appropriate frame (I or B or P).
- Selection of particular region in a frame.
- Selection of watermark strength in a particular frame and across the frames.
- Compensation of drifting in motion vectors.

Compressed Domain Algorithm …

- Intra-frame perceptual adaptability:
  - Adaptive fusion of host-frame and watermark:

$$C_W(i,j) = \alpha_n \times C(i,j) + \beta_n \times W(i,j)$$

  - For non-edge blocks:

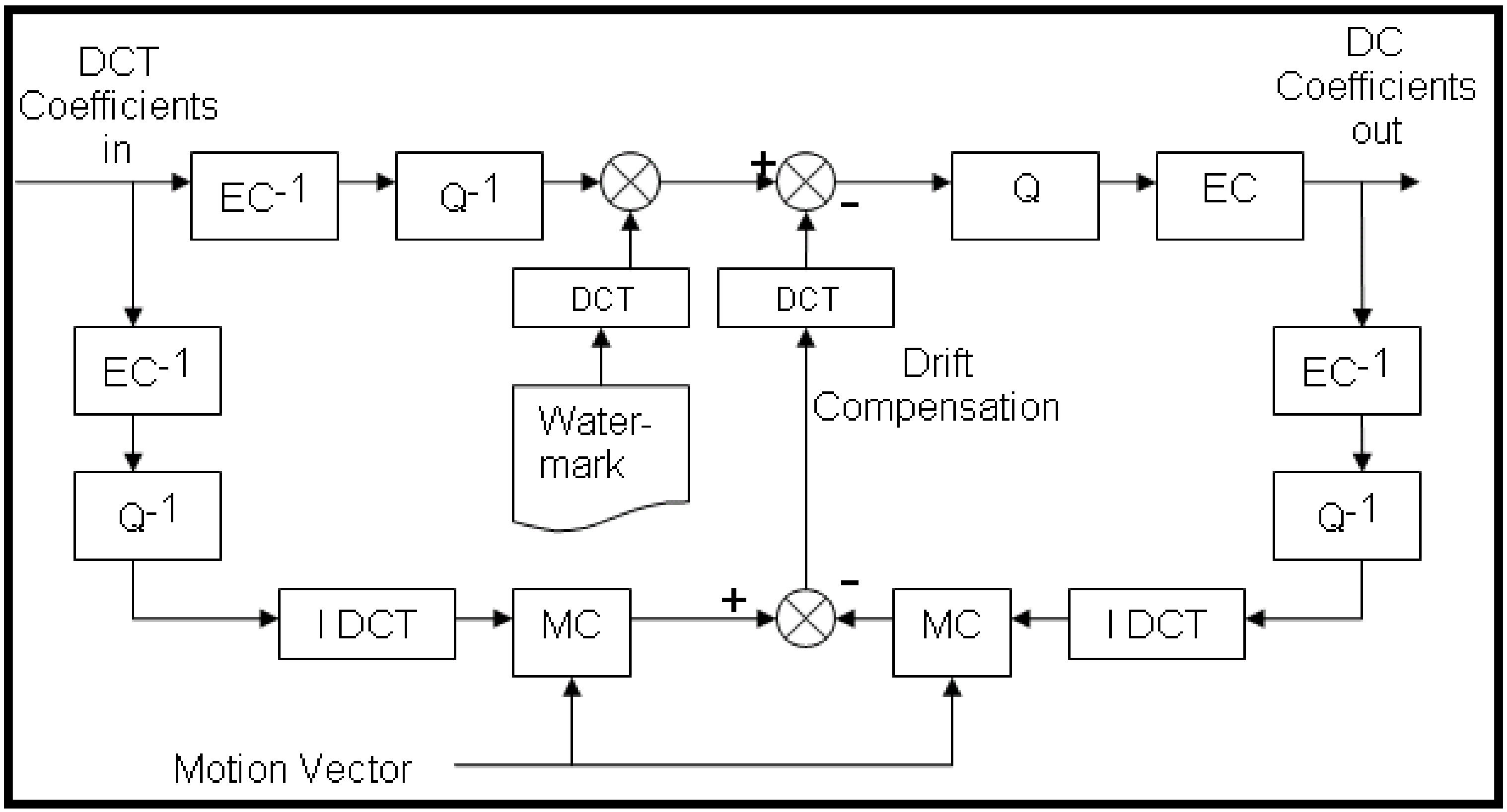
$$\begin{aligned} \alpha_n &= \sigma^*{}_n \times exp\left(-\left(\mu^*{}_n - \mu^*\right)^2\right), \\ \beta_n &= \left(\frac{1}{\sigma^*{}_n}\right) \times \left(1 - exp\left(-\left(\mu^*{}_n - \mu^*\right)^2\right)\right). \end{aligned}$$

  - For edge blocks: user defined α and β.

- Inter-frame perceptual adaptability: Predetermine the coefficients from benchmark frames and store them in buffer.

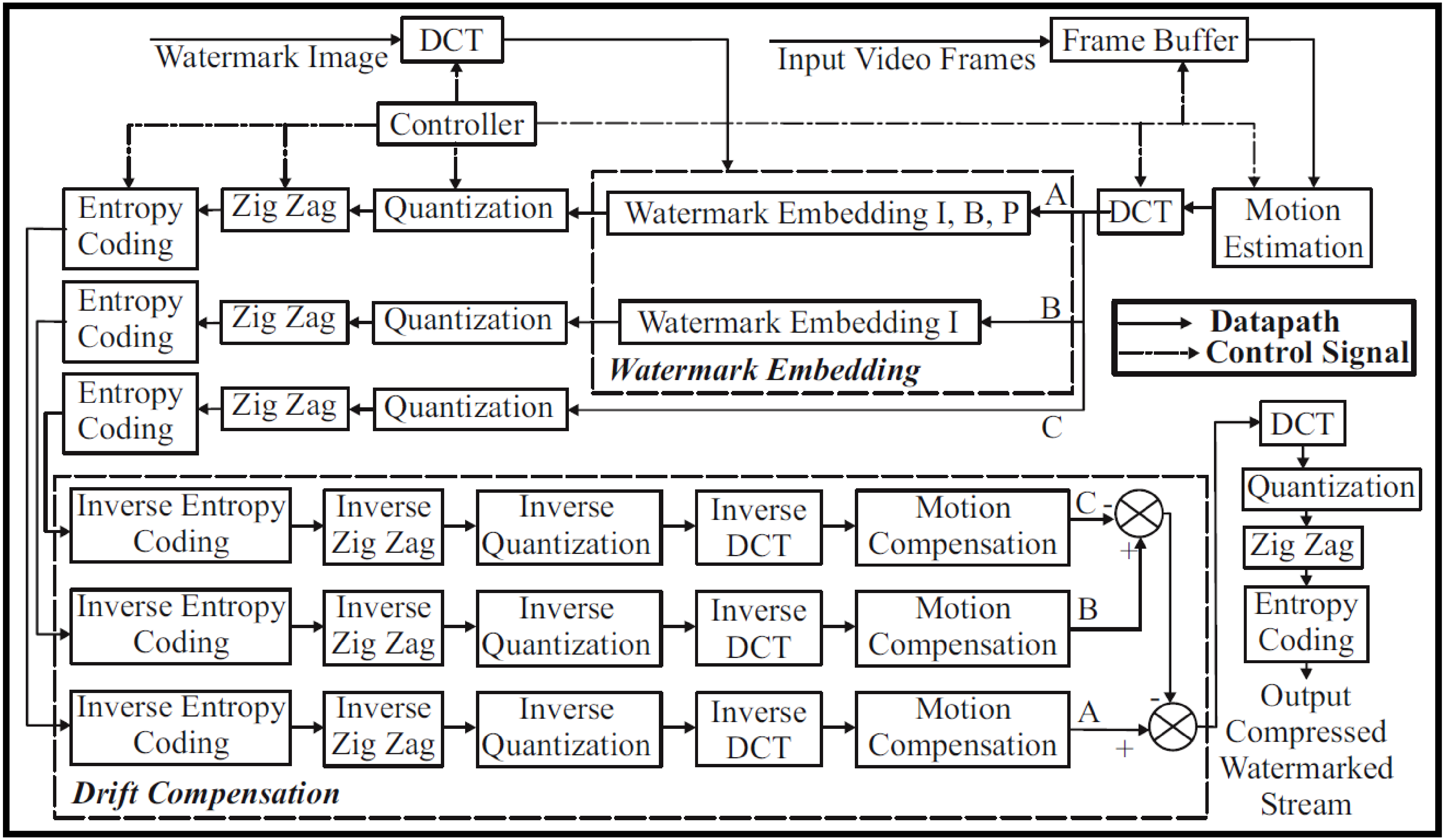
Compressed Domain Algorithm … (Drift Compensation)

- Watermark drifts in compressed domain.
- Drift Compensation cancels the side effect of drift.



Proposed Watermarking Architecture

Proposed Watermarking Architecture



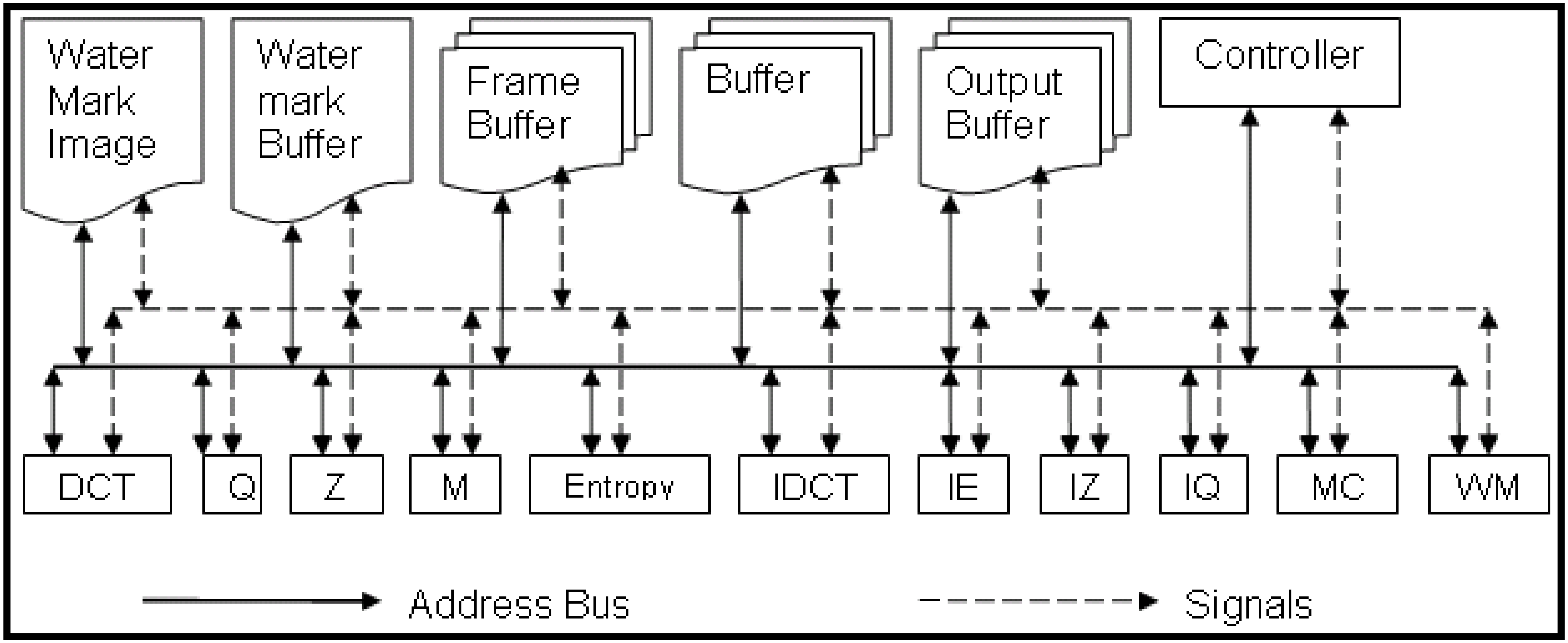
Watermarking Architecture: Main Components …

1) **Watermark embedding IBP**: Embeds a watermark to every frame, I, B, P, sequentially.
2) **Watermark embedding I**: Embeds a watermark to intra frame only.
3) **Frame buffer**: Buffers the frames during intermediate computations by other modules.
4) **Discrete Cosine Transformation (DCT)**: Calculates the DCT coefficients of the video frames and it consists of two 1D DCT sub-modules.
5) **Inverse DCT**: Calculates the inverse DCT coefficients of the video frames.
6) **Motion estimation**: Performs motion estimation using a search for the best match in the current frame and the previous frame.
7) **Motion compensation**: Rebuilds a new frame by resembling original from reference frame, motion vectors, and prediction errors.

Watermarking Architecture: Main Components

8) **Quantization**: Quantizes the DCT coefficients according to predefined quantization tables.
9) **Inverse quantization**: Inverse quantizes the coefficients according to predefined quantization tables.
10) **Zig-Zag**: Performs zig-zag scanning of the DCT for re-ordering of the DCT coefficients.
11) **Inverse Zig-Zag**: Performs inverse zig-zag scanning of the DCT coefficients.
12) **Entropy coding**: Performs entropy coding which is implemented as Huffman coding look up.
13) **Inverse entropy coding**: Performs inverse entropy coding.
14) **Controller**: Generates clocked addressing and control signals to each individual component module in the system to synchronize system functions.

Watermarking Architecture: Control Signals

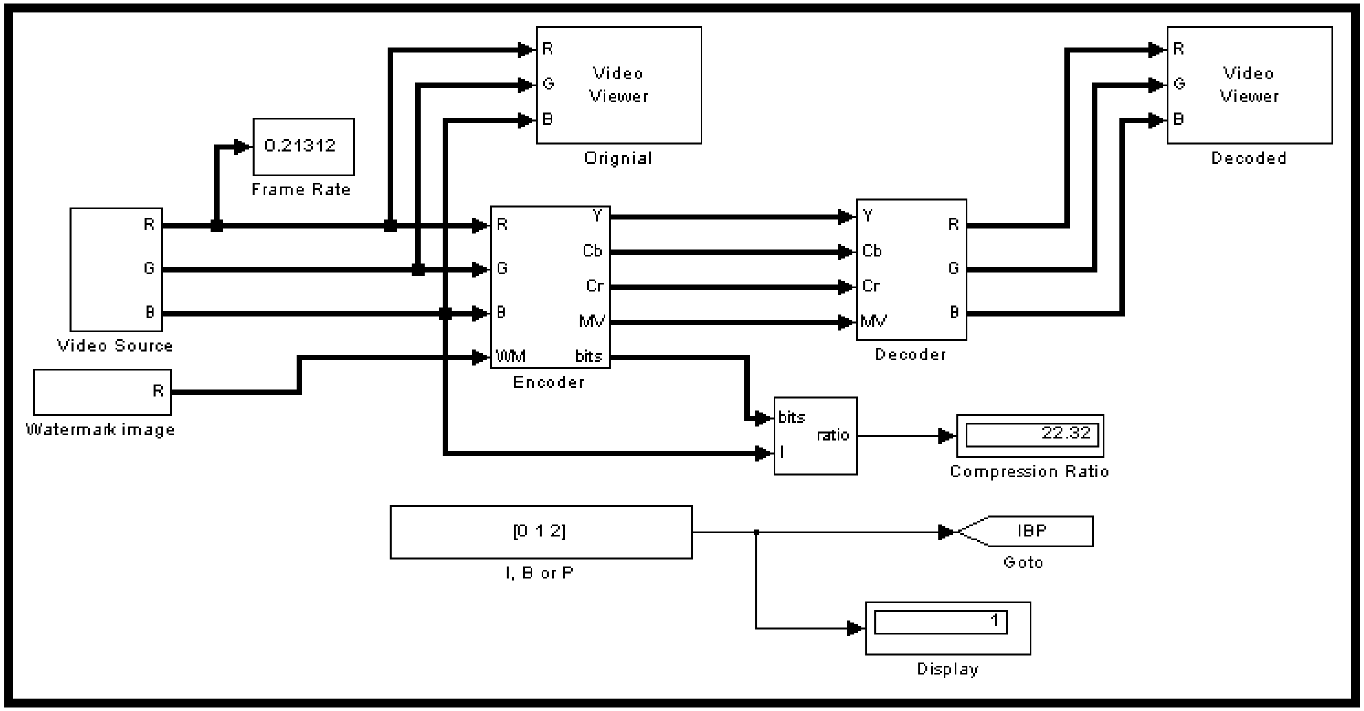


Simulink Prototyping

Simulink Based Modeling … (Advantages)

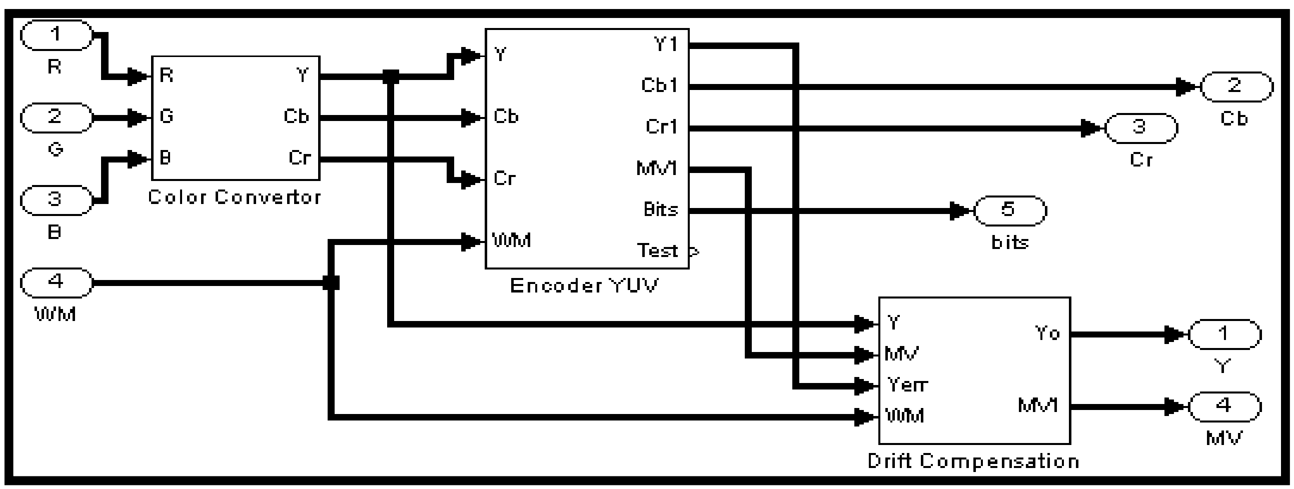
- Simulink offers common video and image processing functions and modules.
- The units such as DCT/IDCT, SAD for Motion Estimation, Block Processing (split), and Delay (Buffer), etc. were directly used.
- Units such as Quantization, Zig-zag scanning and Entropy coding are easily built.

Simulink Based Modeling …



Overall Architecture

Watermarking Encoder



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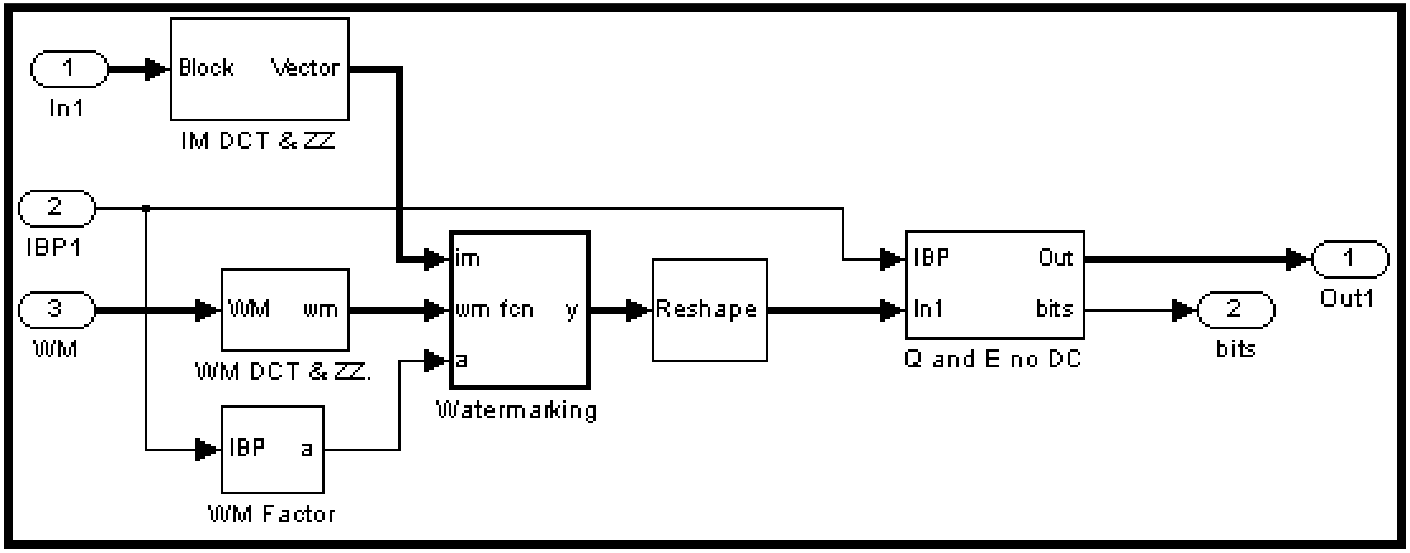
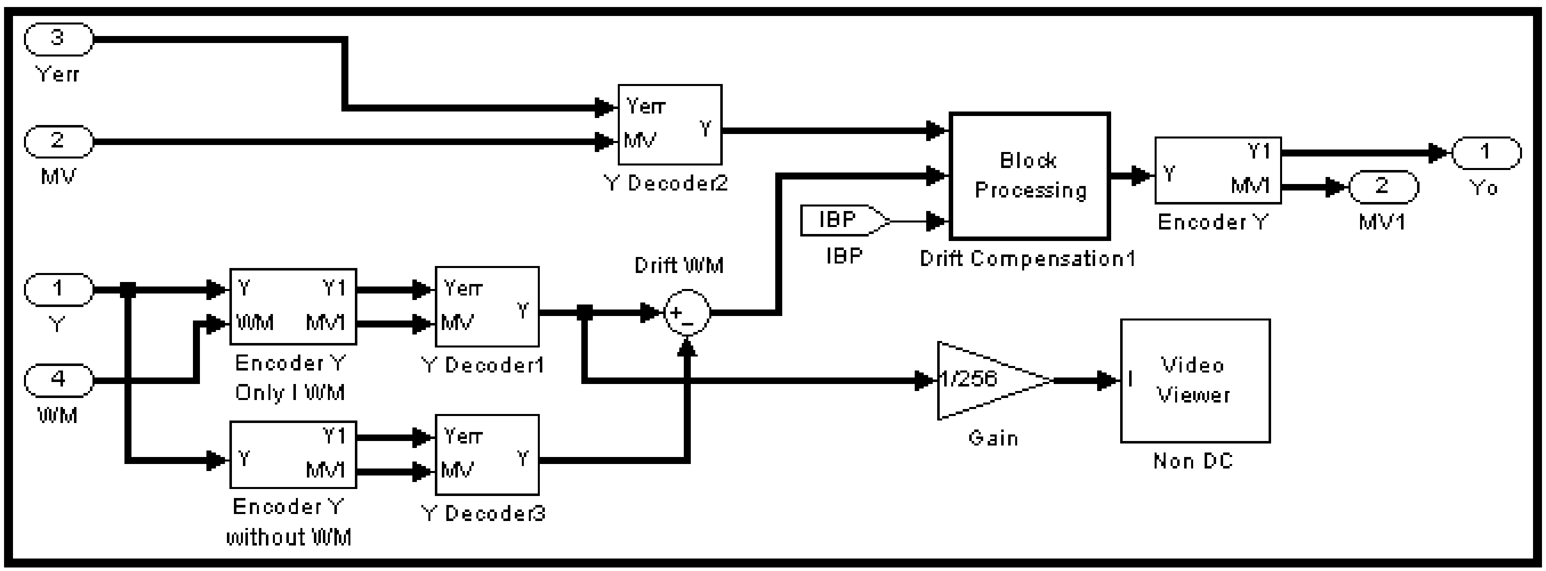
Simulink Based Modeling



Watermarking Encoder YUV

Drift Compensation Module



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Experimental Results

Experimental Results: Test Video …

Watermark - 1

Original Bird Video

Watermarked Bird Video

Experimental Results: Test Video …

Watermark -1

Original Dinner Video

Watermarked Dinner Video

Experimental Results: Test Video …

Watermark - 2

Original Bird Video

Watermarked Bird Video

Experimental Results: Test Video …

Watermark - 2

Original Dinner Video

Watermarked Dinner Video

Experimental Results: Performance Measurement

$$MSE = \frac{\sum_{m=1}^{M} \sum_{n=1}^{N} \sum_{k=1}^{3} |p(m,n,k) - q(m,n,k)|^2}{3 \times M \times N}$$

$$PSNR = 10 \times \log_{10} \left(\frac{(2^i - 1)^2}{\text{MSE}} \right)$$

- Average PSNR of watermarked compressed video is 20-30*dB.*
- The low *dB* did not degrade the perceptual quality of the video, as it is due to the fact that the watermark is visible.
- Results are consistent with visible watermarking algorithms and architectures available in the literature [4], [8], [9].

Conclusions

Conclusions

- An MPEG-4 watermarking system is presented.
- The architecture for the visible watermarking algorithm was prototyped using Simulink.
- Motion Estimate causes the greatest time delay in whole system. DCT costs most complex unit of the architecture.
- Video watermarking in DCT domain is robust to attacks.
- Watermarking at uncompressed domain is fast and low.
- Watermarking with drift compensation at compressed domain achieves same quality as in uncompressed.
- The watermark is embedded in compressed video, thus video processing is performed when one content provider sends compressed video to different broadcasting stations.

Thank You !!!

The presentation is available at:

http://www.cse.unt.edu/~smohanty