Video Compression Standards (II)

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Tutorial 2 : Image/video Coding Techniques

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Basic Transform coding *Tutorial 2*

- Discrete Cosine Transform
  - For a 2-D input block U, the transform coefficients can be found as $Y = CUC^T$
  - The inverse transform can be found as $Y = CUC^T$
  - The NxN discrete cosine transform matrix C=c(k,n) is defined as:

$$c(k,n) = \begin{cases} \dfrac{1}{\sqrt{N}} & for\ k = 0\ and\ 0 \le n \le N-1, \\ \sqrt{\dfrac{2}{N}} \cos \dfrac{\pi(2n+1)k}{2N} & for\ 1 \le k \le N-1\ and\ 0 \le n \le N-1. \end{cases}$$

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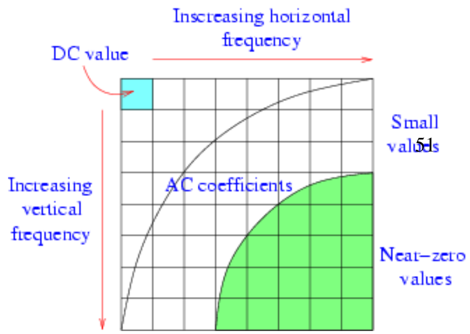
Basic Transform coding *Tutorial 2*

- The distribution of 2-D DCT Coefficients

Ref: H. Wu



$$\begin{bmatrix} 68 & 3 & 5 & -2 & 0 & 0 & -2 & 0 \\ -10 & 0 & -4 & 3 & 0 & 0 & 0 & 0 \\ 9 & 3 & 0 & 0 & 0 & -2 & 0 & 0 \\ 3 & 2 & 0 & 3 & 0 & 2 & -2 & 0 \\ 0 & 0 & 2 & -2 & 0 & 0 & 0 & 0 \\ 0 & 2 & -2 & 2 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

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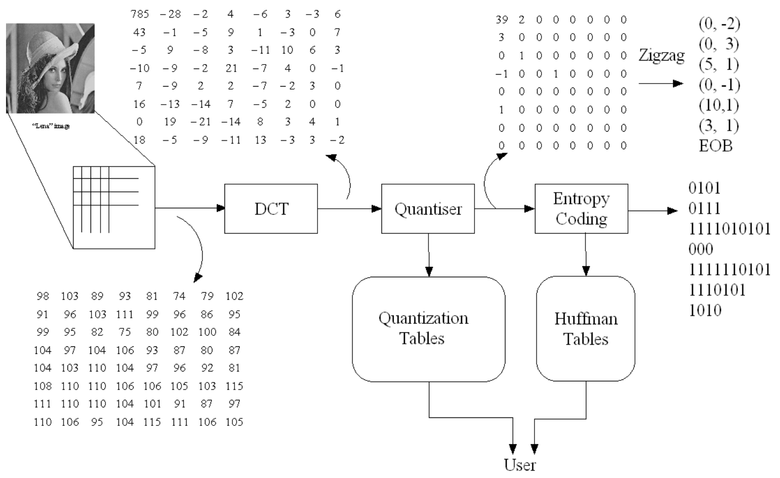
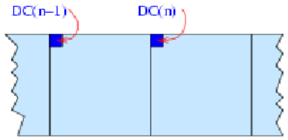
JPEG DCT-Based Encoding *Tutorial 2*



Coding of DCT Coefficients (DC)
Tutorial 2

- DC coefficient is coded differentially as (size, amplitude). There are 12 size categories



$\Delta DC_i = DC_i - DC_{i-1}$

-3 36 39

Size: 2

-3	00
-2	01
2	10
3	11

Final code:01100

[Coeff]	Size	[Code]	Length
0	0	00	2+0
1	1	010	3+1
2..3	2	011	3+2
4..7	3	100	3+3
8...15	4	101	3+4
16..31	5	110	3+5
32..63	6	1110	4+6
64..127	7	11110	5+7
128..255	8	111110	6+8
256..511	9	1111110	7+9
512..1023	10	11111110	8+10
1024..2047	11	111111110	9+11

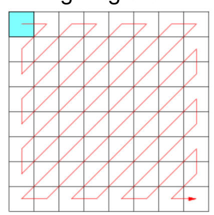
Coding of DCT Coefficients (AC)
Tutorial 2

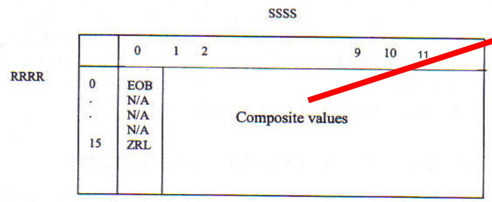
- AC coefficients are re-arranged to a sequence of **(run, level)** pairs through a zigzag scanning process
- Level is further divided into **(Size Categories, Amplitude).**
- Run and size are then combined and coded as a single event (2D VLC)
  - An 8-bit code 'RRRRSSSS' is used to represent the nonzero coefficients
    - The SSSS is defined as size categories from 1 to 11
    - The RRRR is defined as run-length of zeros in the zig-zag scan or number of zeros before a nonzero coefficient
    - The composite value of RRRRSSSS is then Huffman coded

Ex: 1) RRRRSSSS=11110000 represents 15 run '0' coef. and followed by a '0' coef.
2) Multiple symbols used for run-length of '0' coef. exceeds 15
3) RRRRSSSS=00000000 represents end-of-block (EOB)

Coding of DCT Coefficients (AC)
Tutorial 2

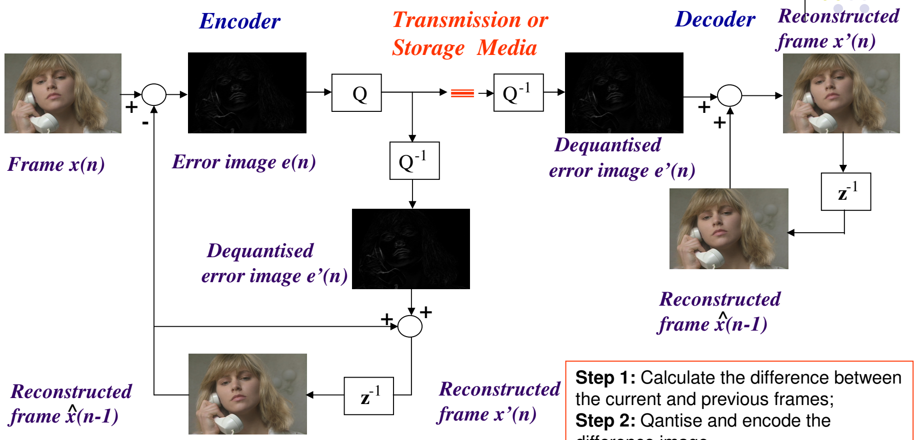
Zig-Zag scan





Zero Run	Category	Code length	Codeword
0	1	2	00
0	2	2	01
0	3	3	100
0	4	4	1011
0	5	5	11010
0	6	6	111000
0	7	7	1111000
.	.	.	.
.	.	.	
1	1	4	1100
1	2	6	111001
1	3	7	1111001
1	4	9	111110110
.	.	.	.
.	.	.	.
2	1	5	11011
2	2	8	11111000
.	.	.	.
.	.	.	.
3	1	6	111010
3	2	9	111110111
.	.	.	.
.	.	.	.
4	1	6	111011
5	1	7	1111010
6	1	7	1111011
7	1	8	11111001
8	1	8	11111010
9	1	9	111111000
10	1	9	111111001
11	1	9	111111010
.	.	.	.
.	.	.	.
EOB		4	1010

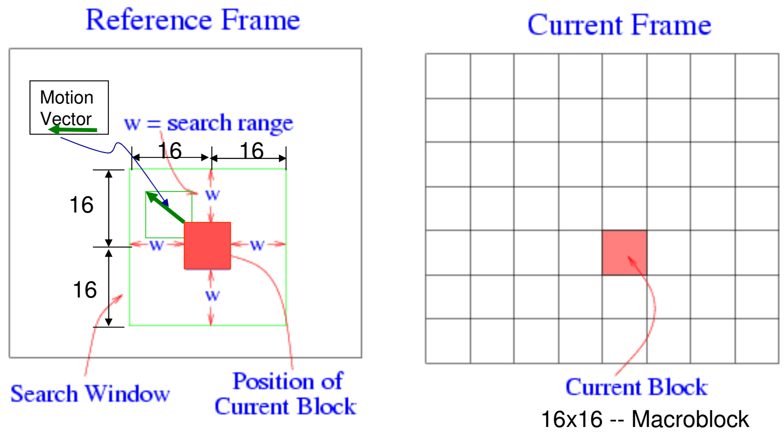
Inter-frame Encoder *Tutorial 2*



Step 1: Calculate the difference between the current and previous frames;
Step 2: Qantise and encode the difference image.
Step 3: Add the dequantised (residual) image to the previous frame to reconstruct the current frame of image.

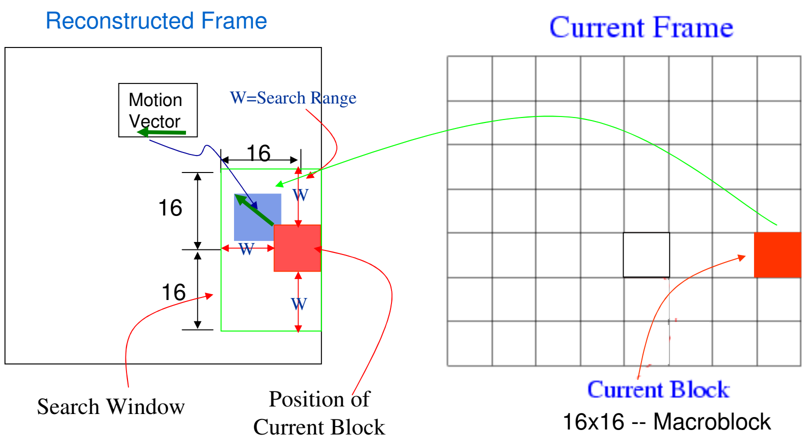
Block Based Motion Estimation
Tutorial 2

- Block base search



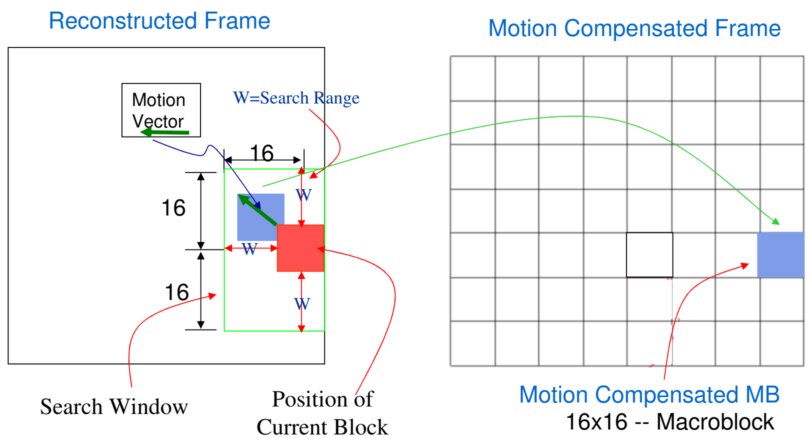
Block Based Motion Estimation
Tutorial 2

- Block base search

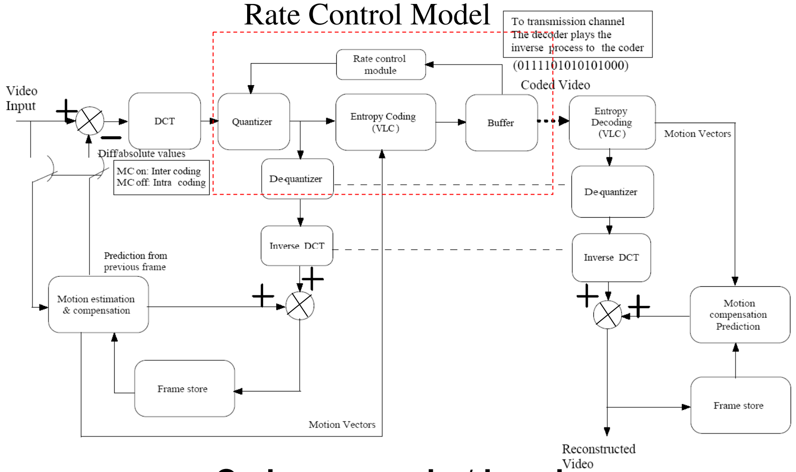


Block Based Motion Estimation
Tutorial 2

- Block base search



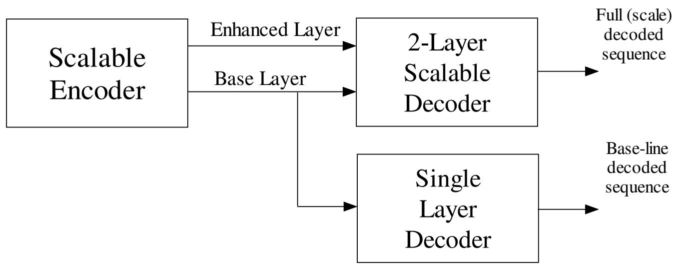
Digital Video Coding (DVC) Structure – Hybrid MC/DPCM/DCT *Tutorial 2*



Codec = encoder/decoder

4.1 Digital Video Coding (DVC) Standards– MPEG-2 Scalability

- Scalable video coding means the ability to achieve more than one video resolution or quality simultaneously.

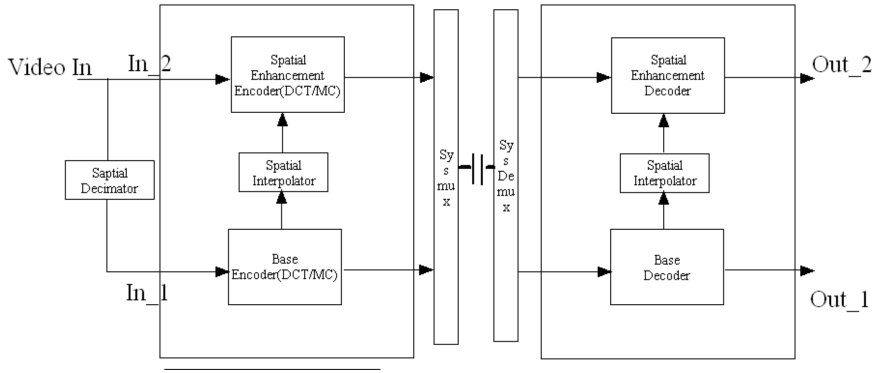


4.1 Digital Video Coding (DVC) Standards– MPEG-2 Scalability

- Spatial Scalability
  - A spatially scalable coder operates by filtering and decimating a video sequence to a smaller size prior to coding.
  - An up-sampled version of this coded base layer representation is then available as a predicator for the enhanced layer
  - As prediction is performed in the spatial domain, the coding at the base layer can take any other standards including (MPEG-1 or H.261).
  - This is an important feature to address compatibility in layered codec

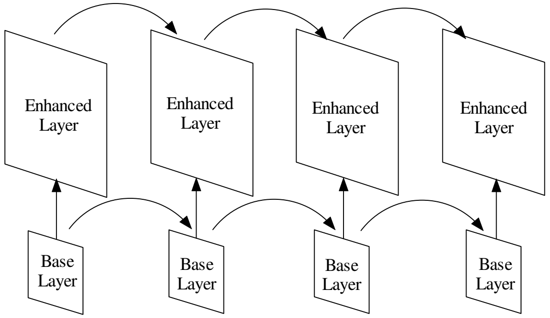
4.1 Digital Video Coding (DVC) Standards– MPEG-2 Scalability

- Spatial Scalability – Spatial Scalability Codec

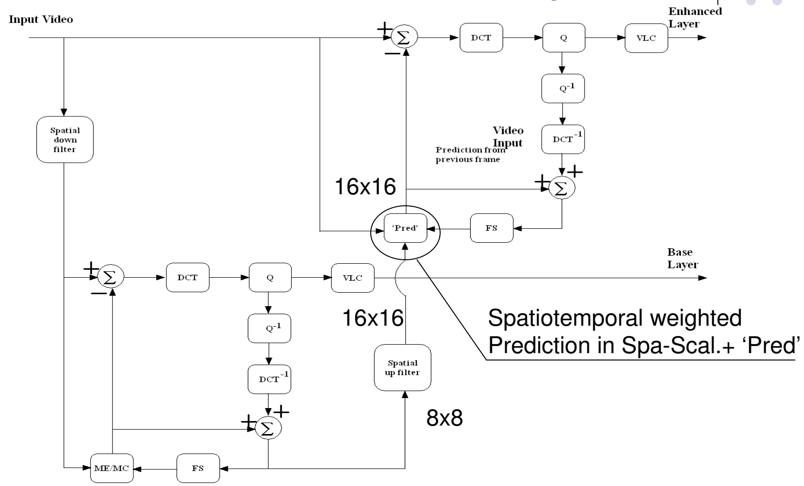


4.1 Digital Video Coding (DVC) Standards– MPEG-2 Scalability

- Spatial Scalability Types
  - Progress to progress
  - Progress to interlaced
  - Interlaced to progress
  - Interlaced to interlaced



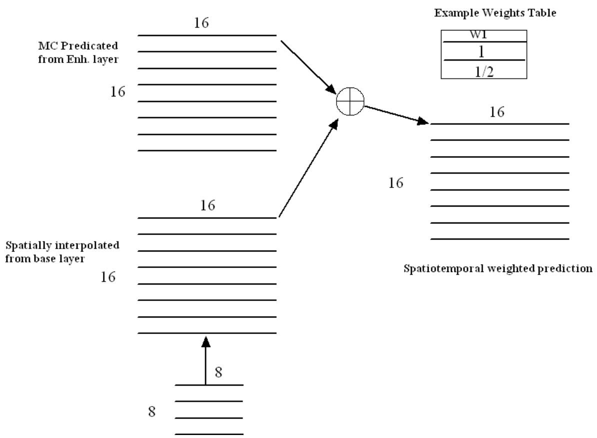
4.1 Digital Video Coding (DVC) Standards– MPEG-2 Scalability



2 layer spatially scalable coder

4.1 Digital Video Coding (DVC) Standards– MPEG-2 Scalability

- Spatiotemporal weighted Prediction

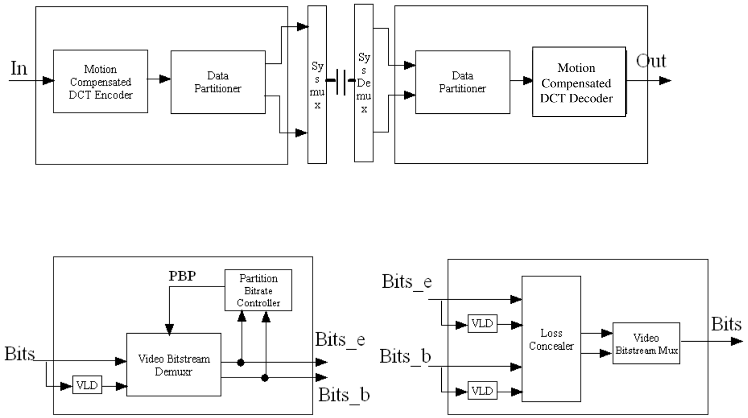


4.1 Digital Video Coding (DVC) Standards– MPEG-2 Scalability

- Data partitioning
  - Data partitioning permits a video bitstream to be divided into two separate bitstreams
    - The BL contains the more info. including address and control info. as well as lower order DCT coef.
    - The HL contains the rest info. of the bitstream
    - The syntax elements in BL are indicated by proprity breakpoint (PBP)
    - Some syntax elements in BL are redundant in HL to facilitate error recovery
  - It has the advantage to introduce almost no additional overhead
  - The disadvantage of this scheme: considerable drift occurs if only the BL is available to a decoder.

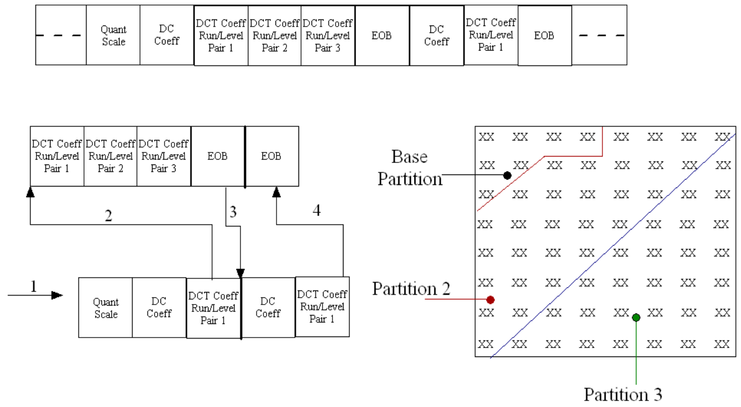
4.1 Digital Video Coding (DVC) Standards– MPEG-2 Scalability

- Data partitioning



4.1 Digital Video Coding (DVC) Standards– MPEG-2 Scalability

- Data partitioning – bitstream example (PBP = 64)



4.1 Digital Video Coding (DVC) Standards– MPEG-2 Scalability

- Data partitioning

Priority Break Point	Definition
65	All data at sequence, GOP, Pic and slice layers
66	PBP=65 plus MB data to MB type
67	PBP=66 plus data to MB motion Vectors
0	PBP=67 plus MB data from CBP to DC (or 1st non-zero) Coeff.
1	PBP=0 plus to first coeff. Following DC to first non-zero coeff after the first coeff. in the scan order
2	PBP=0 plus up to first non-zero coeff after the 2nd coeff in the scan order
j	PBP=0 plus to first non-zero coeff after the jth coeff in the scan order

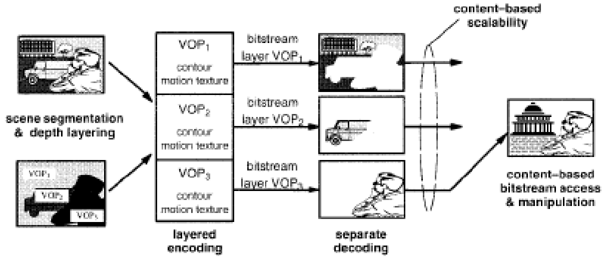
4.2 MPEG-4 visual standard

- Video Coding and Communication
  - MPEG-4 standard: video part -- content based video coding scheme
    - To enable all these content-based functionalities, MPEG-4 relies on a revolutionary, content based representation of audiovisual objects.
    - As opposed to classical rectangular video (eg: MPEG1/2), MPEG-4 treats a scene as a composition of several objects that are separately encoded and decoded
  - The scalability at the object or content level enables to distribute the available bit-rate among the objects in the scene
    - Visually, more important objects are allocated more bits.
  - Encoded once and automatically played out at different rates with acceptable quality for the communication environment and bandwidth at hand.

4.2 MPEG-4 Visual Standard

- Access and manipulation of arbitrarily shaped images

Ref: Thomas Sikora



Object Based MPEG-4 Video Verification Model

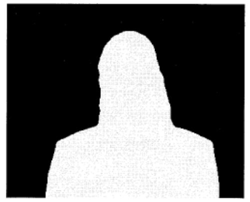
1. In MPEG-4, scenes are composed of different objects to enable content-based functionalities.
2. Flexible coding of video objects
3. Coding of a "Video Object Plane" (VOP) Layer

4.2 MPEG-4 Visual Standard

- Video Object Planes (VOP's)

Ref: Thomas Sikora

Original



Binary Segmentation Mask

The binary segmentation Mask is to extract the back/fore-ground layers

Ref: MPEG-4 AKIYO testing video sequence

4.2 MPEG-4 Visual Standard

- Decomposition into VOP's

Ref: Thomas Sikora

Background Layer VOP

Foreground Layer VOP

The overlapping VOP's brining the opportunity to do the manipulation of Scene content

4.2 MPEG-4 Visual Standard

- Video Object Plane" layered coding

Ref: Thomas Sikora

MPEG-4 VOP-coder

Arbitrary VOP → | Shape | Motion (MV) | Texture DCT | → bitstream

Similar to H.263

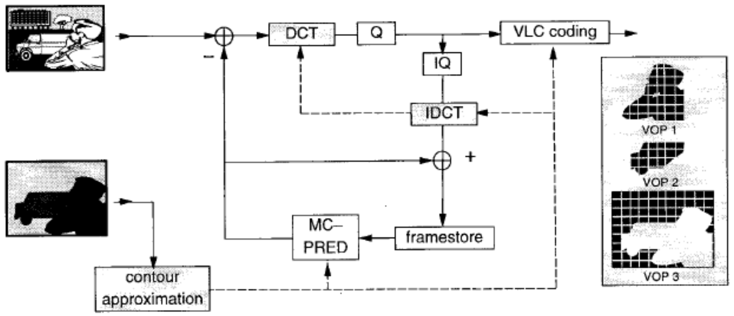
Rectangular VOP → | Motion (MV) | Texture DCT | → bitstream

Similar to H.263

4.2 MPEG-4 Visual Standard

- DCT-Based Approach for Coding VOP's

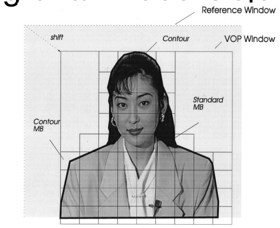
Ref: Thomas Sikora



Block diagram of the basic MPEG-4 hybrid DPCM/transform codec structure

4.2 MPEG-4 Visual Standard

- Coding of a "Video Object Plane"



Ref: Thomas Sikora

4.2 MPEG-4 Visual Standard

- Background Padding for Motion Compensation

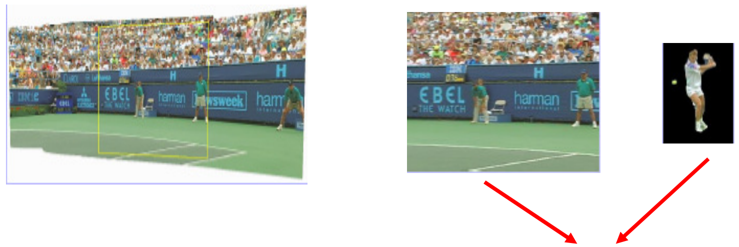
Padded background

Ref: Thomas Sikora

Previous Frame

Current Frame

4.2 MPEG-4 Visual Standard
One Typical Example -- Sprite Coding

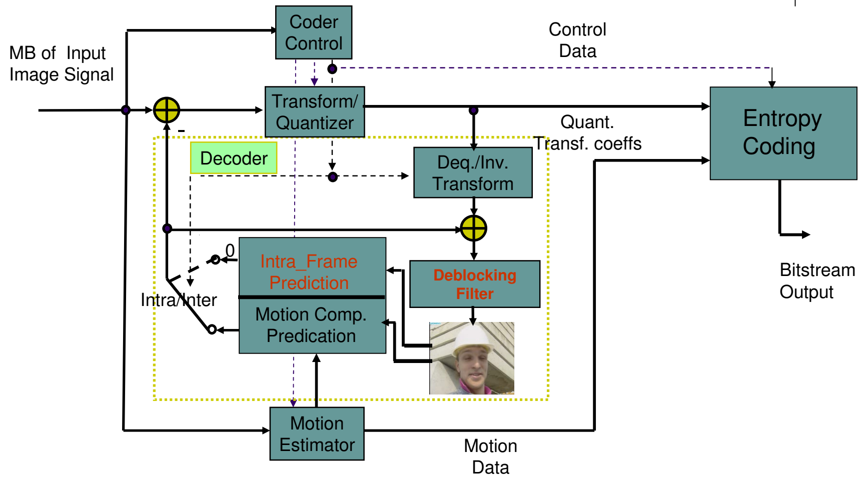


1. A non-changing background only has to be transmitted once
2. Only foreground objects transmitted and re-Inserted at the decoder
3. Object are much smaller than full video

4.3 Introduction to H.264 Video Coding Standard

- It started from the ITU-T H.26L Project (Long term)
- It aims to improve the coding efficiency up to 50% compared to MPEG-4 video coding standard
- In Dec. 2001, MPEG and ITU-T experts set up joint video team (JVT) to focus on this new standard.
- The final version of the standard has been approved by ITU-T 2003. H.264 video coding standard or MPEG-4 Part 10.
- The new technical approaches:
  - An Adaptive deblocking loop filter to remove the artifacts
  - Multiple frame for ME/MC
  - Predication in Intra mode
  - Integer transform
  - Optimized rate control strategy (my opinion)

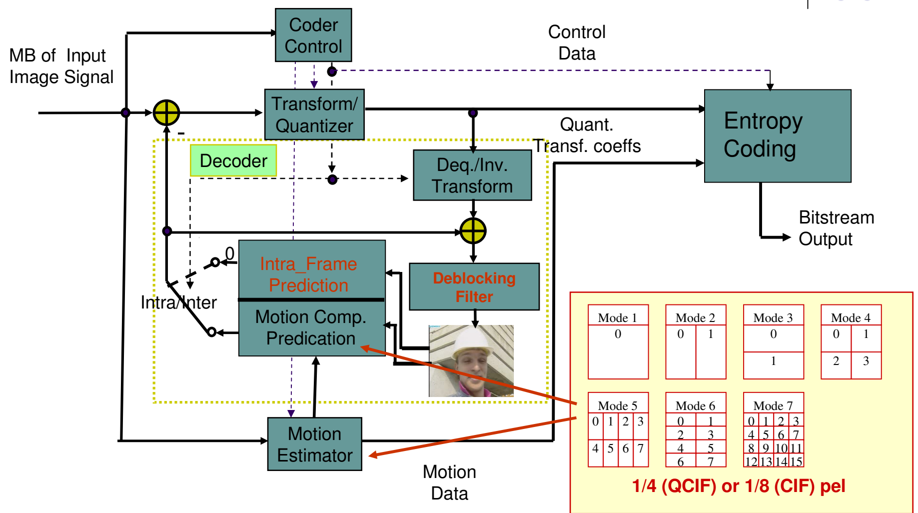
4.3 Video Codec Structure of H.264



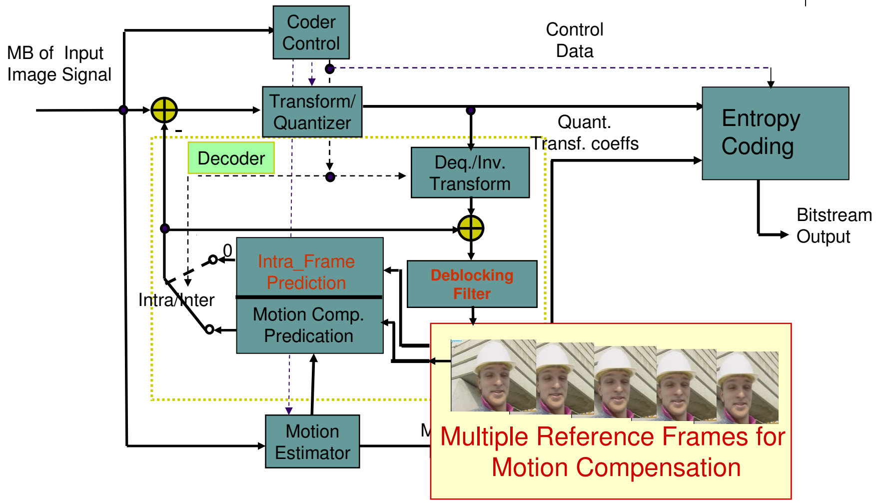
4.3 Video Codec Structure of H.264 (H.26L TML-8 Design Part 1 of 4)

- Hybrid of DPCM/MC/Trans coding as in Prior standards. Common elements include:
  - 16x16 macroblocks
  - Conventional sampling of chrominance and association of luminance and chrominance data
  - Block motion displacement
  - Motion vectors over picture boundaries
  - Variable block-size motion
  - Block transforms (not DCT, wavelets or fractals)
  - Scalar quantization (weighted)

4.3 H.264: Motion Compensation Accuracy



4.3 H.264: Multiple Reference Frames



4.3 H.264: Multiple Reference Frames

- Motion Compensation:
  - Multiple reference pictures (per H.263++ Annex U)
  - B picture prediction weighting
  - New “SP” transition pictures for sequence switching
  - Various block sizes and shapes for motion compensation (7 segmentations of the macroblock: 16x16, 16x8, 8x16, 8x8, 8x4, 4x8, 4x4)
  - 1/4 sample (sort of per MPEG-4) and 1/8 sample accuracy motion