Digital Video Applications

Asymmetric Applications: (=compression once, decompression frequently)

- Electronic Publishing
  —Education and Training
  —Travel Guidance
  —Videotext
  —Point-of-Sale
- Games
- Entertainment (movies)

Symmetric Applications: (=equal use of compression and decompression)

- Electronic Publishing (production)
- Video Mail
- Videotelephone
- Video Conferencing

Features of the Video Compression Algorithm

- Random Access (need special consideration for video on CD)
- Fast Forward/Reverse Searches
- Reverse Playback
- Audio-Video Synchronization
- Robustness to Errors
- Coding/Decoding Delay
- Editability (construct editing unit in short time and coded only with reference)
- Format Flexibility (raster size and frame rate)
- Cost Trade-offs

Overview of MPEG Compression Algorithm

The challenge:

- require high compression ratio not achievable by the intraframe coding.
- the random access are best satisfied by pure intraframe coding.
- A delicate balance between intraframe and interframe coding

MPEG video compression algorithm replies on two basic techniques:

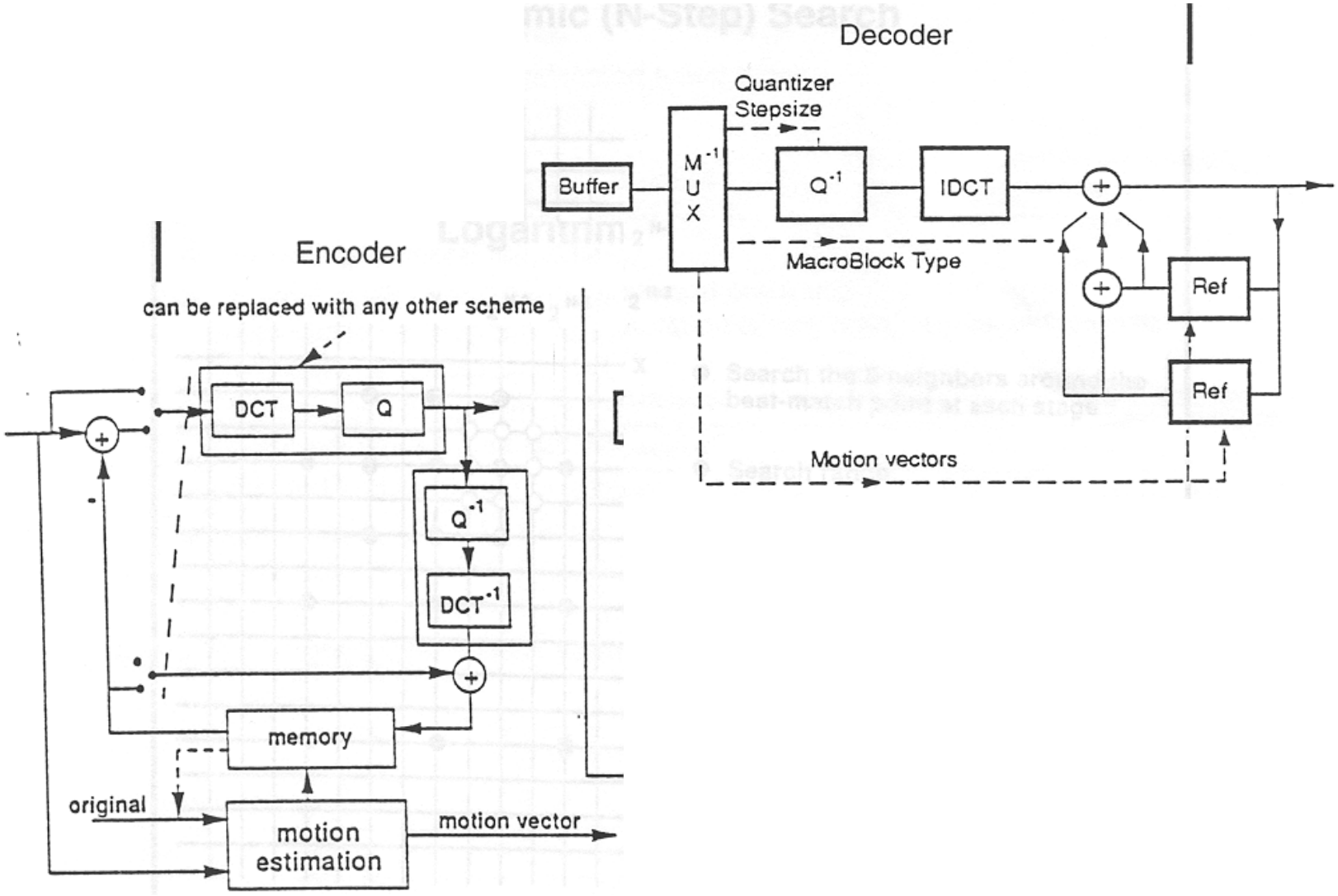
- **block-based motion compensation**—reduce temporal redundancy.
  16x16 block (called macroblock), interframe
- **DCT-based compression**—reduce spatial redundancy.
  8x8 block, intraframe

Motion compensation is a technique the assume the current picture can be modelled as a translation of the picture at some previous time.

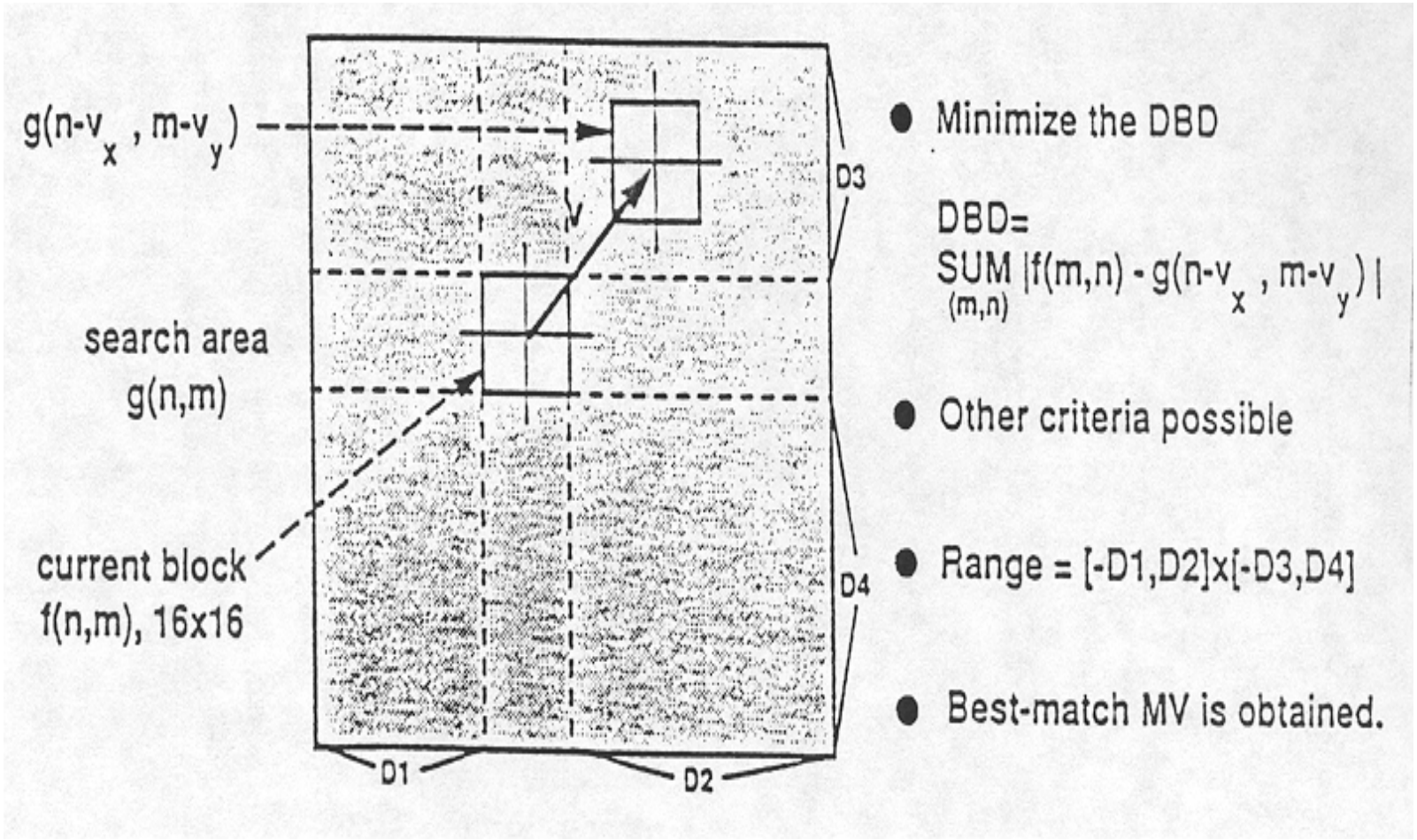
Motion estimation is a process to estimate the translation (called **motion vector**, including amplitude and direction information) between two pictures.

The predication (estimation) errors are encoded and compressed using DCT.

A Typical Interframe Coding Scheme



Motion Estimation-
Full Search Block Matching



- Minimize the DBD

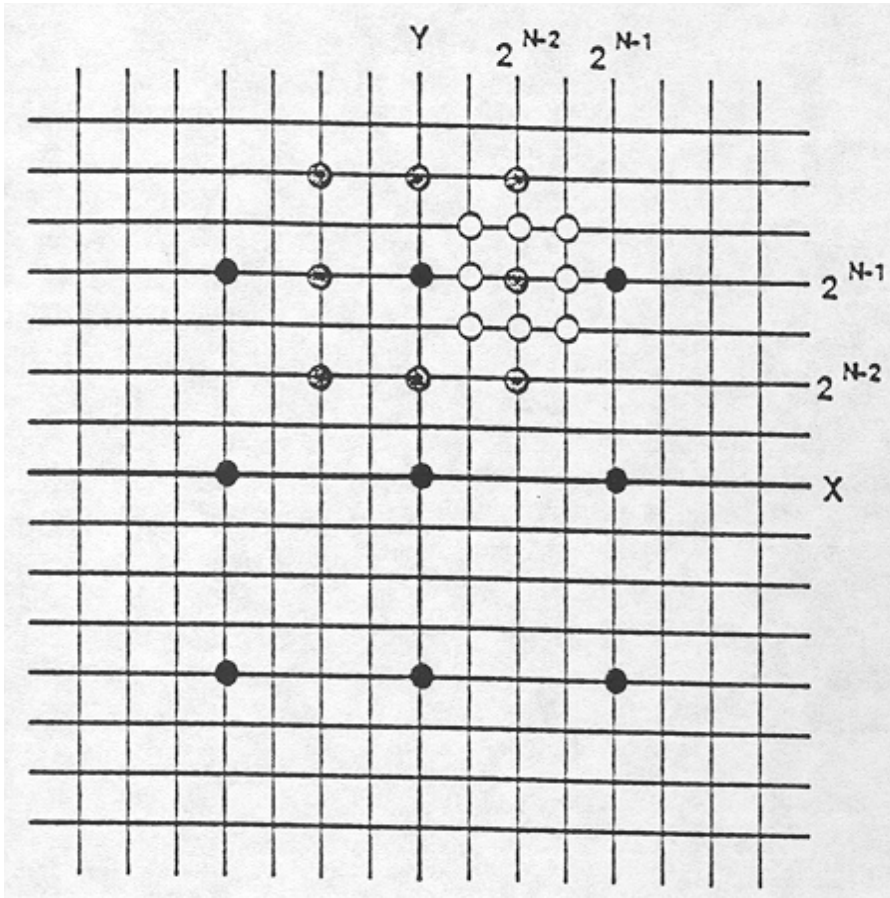
  DBD=
  $\underset{(m,n)}{\text{SUM}} |f(m,n) - g(n-v_x, m-v_y)|$

- Other criteria possible

- Range = [-D1,D2]x[-D3,D4]

- Best-match MV is obtained.

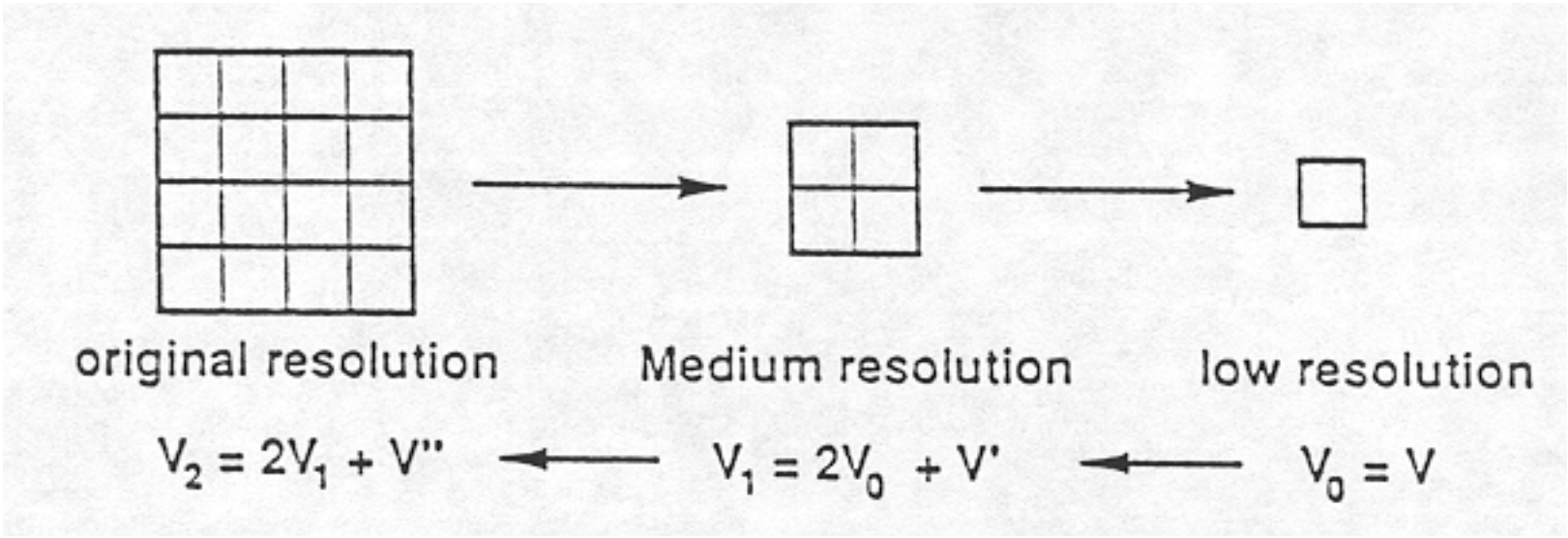
Motion Estimation-
Logarithmic (N-Step) Search



- Search the 8-neighbors around the best-match point at each stage
- Search range

$$[-2^N+1,\ 2^N-1] \times [-2^N+1,\ 2^N-1]$$

Motion Estimation-
Hierarchical and Telescopic Search

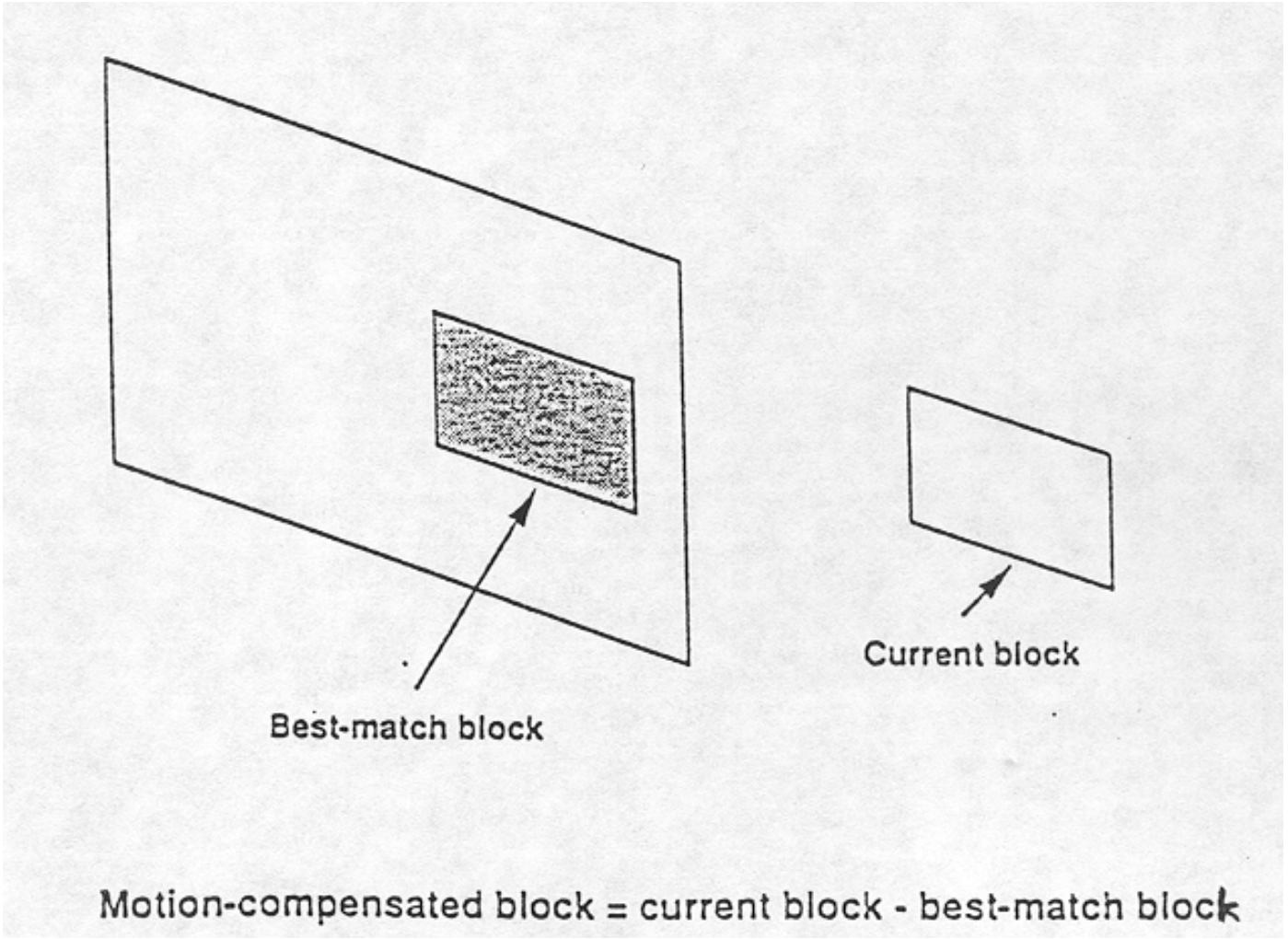


- At each stage. the search range gets smaller.
- The overall MV ranage can be large.

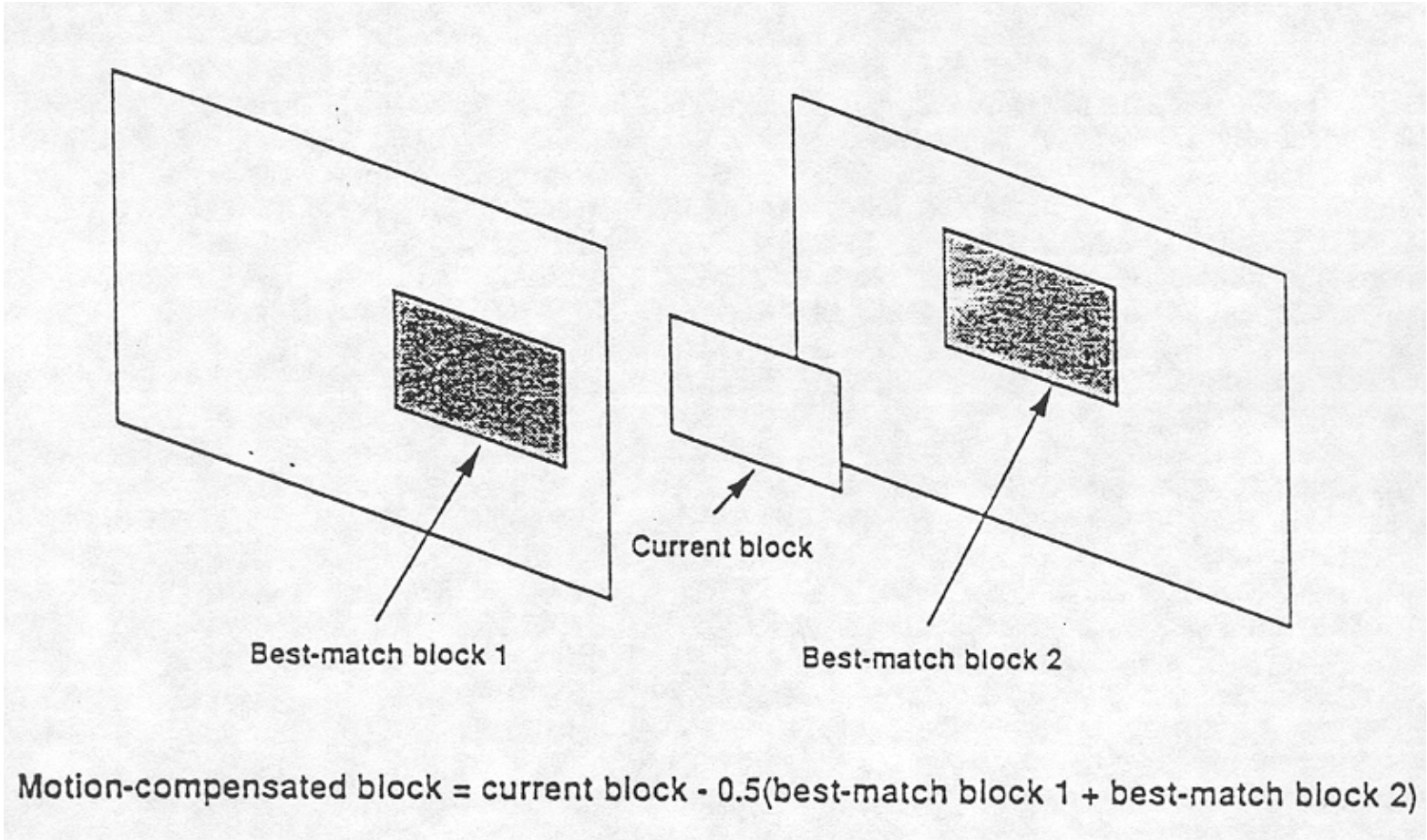
Motion Compensation

- Reducing temporal redundancy
- current block - prediction = estimated future block
  —prediction = best-matched block
  —result in small signal as in DPCM
- Leakage prediction—more robust to errors
  —current block - A x prediction, where A < 1.
- forward and backward prediction
- combination of both forward and backward prediction
  bi-directional prediction (compression ration is very high, require buffering of past and future frames)

Forward Motion Compensation



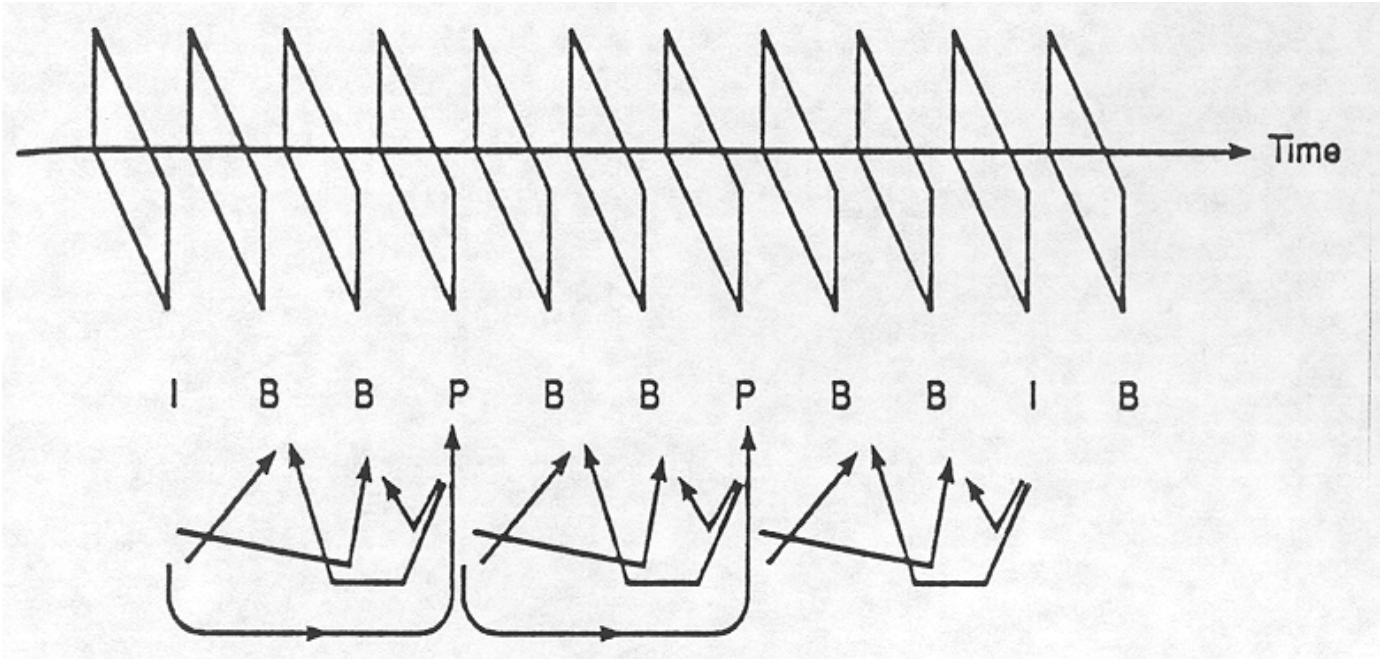
Bi-direction (Interpolated) Motion compensation



Motion-compensated block = current block - 0.5(best-match block 1 + best-match block 2)

Group of Frames Concept

I frame—Intraframe-coded frame
P frame—Predicted frame
B frame—Bi-directionally interpolated frames
The sequence in the group of frames is a compromise between quality and compression ratio.



Syntax of MPEG Video Bit Stream

TABLE 7.

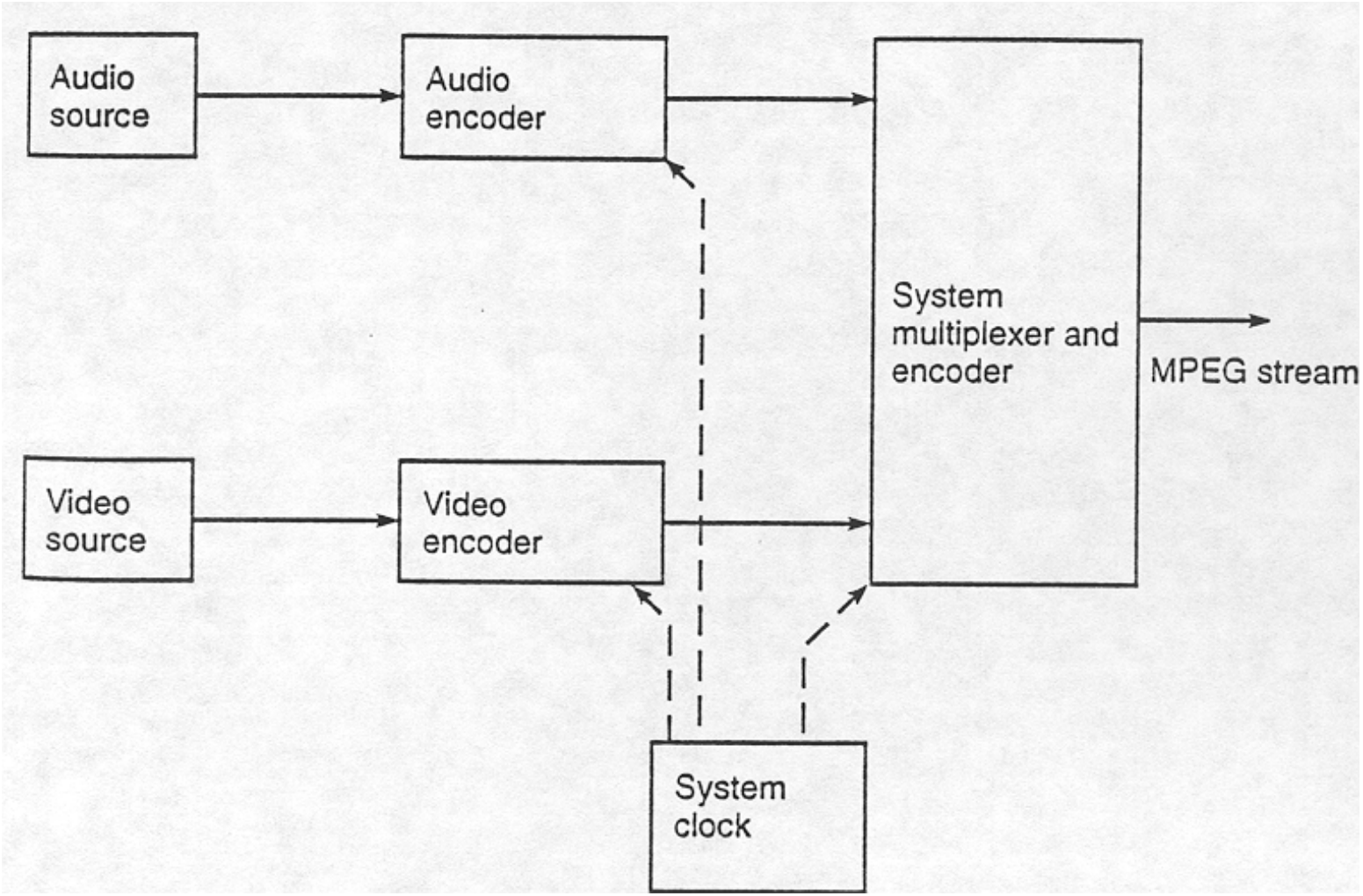
Six Layers of Syntax of the MPEG Video Bit Stream

Sequence Layer:	(Random Access Unit: Context)
Group of Pictures Layer:	(Random Access Unit: Video Coding)
Picture Layer:	(Primary Coding Unit)
Slice Layer:	(Resynchronization Unit)
Macroblock Layer:	(Motion Compensation Unit)
Block Layer:	(DCT Unit)

TABLE 6.

Video Sequence Parameters
Picture Width
Picture Height
Pel Aspect Ratio
Frame Rate
Bit Rate
Buffer Size

Generate Data Stream of MPEG System



Timing and Synchronization in MPEG system

Timing relationship is encoded using time-stamps.

System time clock (STC) is a reference time operating at 90kHz, with 33 bit time values enough to uniquely identify an operating time within 24 hours.

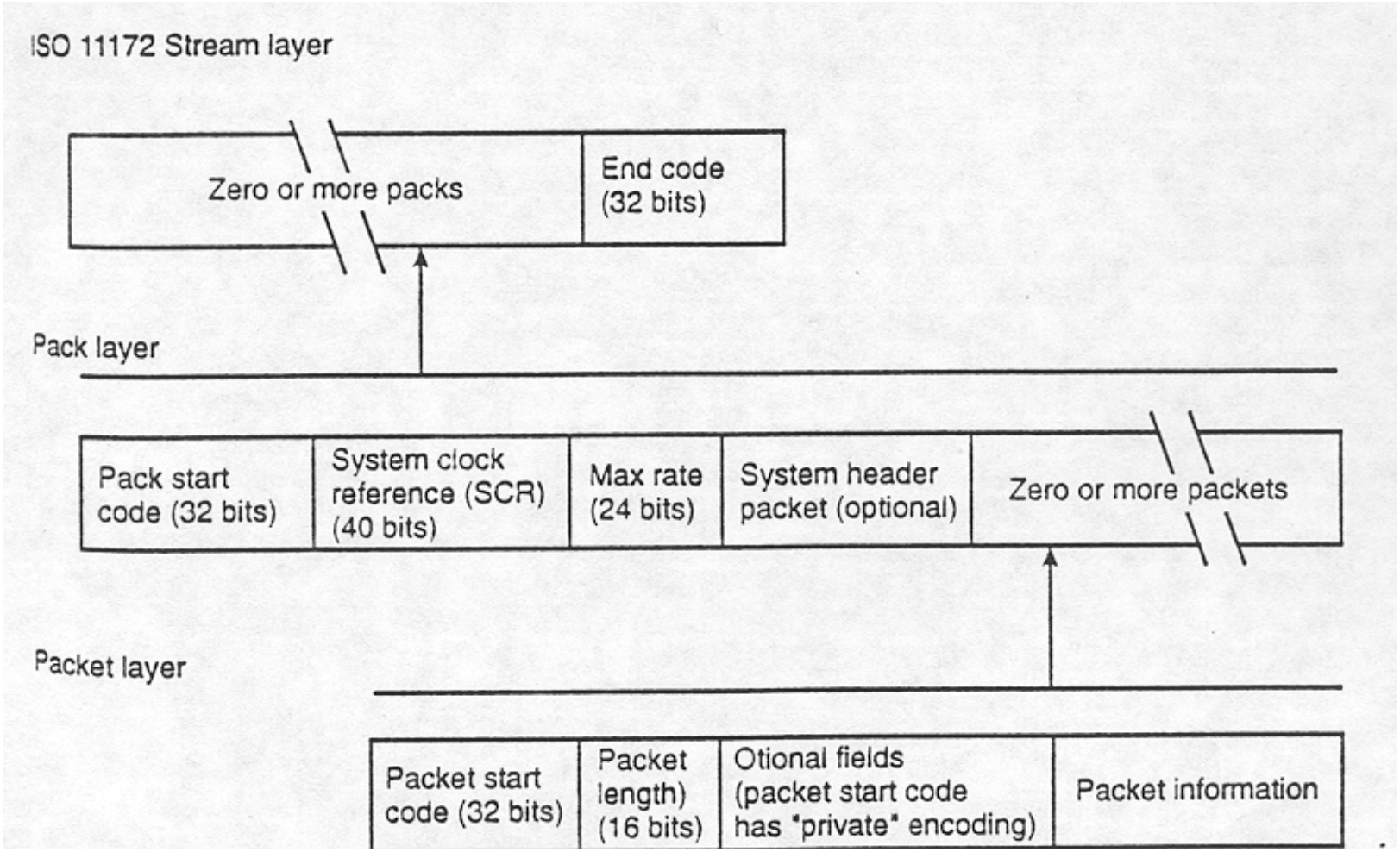
The Video Presentation Unit (VPU) and Audio Presentation Unit (APU) are encoded by current STC value, called Presentation Time Stamp (PTS).

System Clock Reference (SCR) is a time-stamp encoded the value of STC when the last octet of the field exit come out of the system encoder.

For multimedia systems that decode multiple video/audio streams, there must a “time master” in the decoding system.

- it can be any of the decoders, the information source, and external time base.
- all other entities in the system must slave their timing to the master.
- if an decoder is chosen, the time it presents the presentation unit is considered to the correct time.
- if an information-stream source is chosen, the SCR value indicates the correct time at the moment these values are received. The decodes use this information to pace their decoding and presentation timing.

MPEG Stream follows ISO-CD 11172 format



MPEG Constrained Parameter Set

Parameters of the MPEG Constrained Parameter Set
Horizontal size <= 720 pels
Vertical size <= 576 pels
Total number of Macroblocks/picture <= 396
Total number of Macroblocks/second <= 396*25 = 330*30
Picture Rate <= 30 Frames/second
Bit Rate <= 1.86 Mbits/second
Decoder Buffer <= 376832 bits

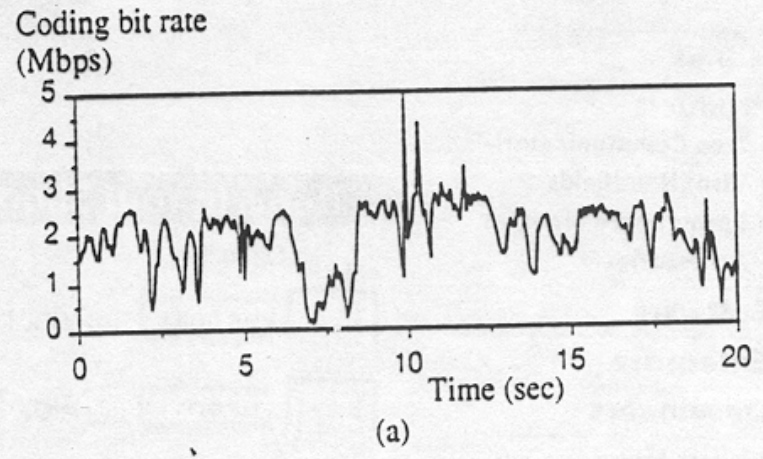
Perspectives of Application of the MPEG Algorithm beyond the Constrained Parameter Set		
Format	Video Parameters	Compressed Bit Rate
SIF	352 × 240 30Hz	1.2–3 Mbps
CCIR 601	720 × 486 30Hz	5–10 Mbps
EDTV	960 × 486 30Hz	7–15 Mbps
HDTV	1920 × 1080 30Hz	20–40 Mbps

Bit-rate variation

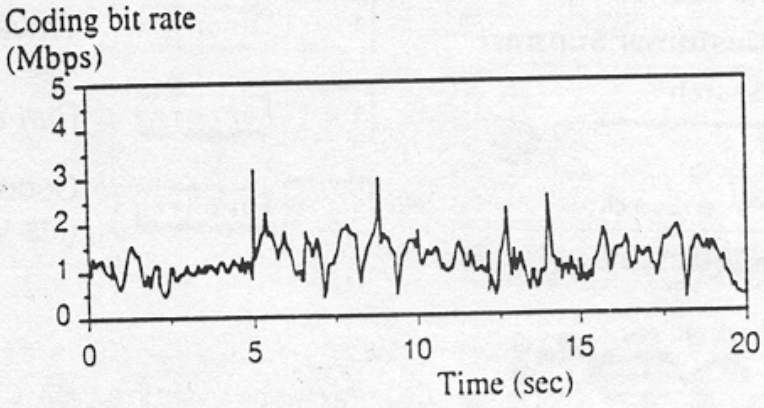
Table 3.3
Burstiness Results

Algorithm	*DPCM*		*MC + DPCM*		*MC + DCT*	
Video sequence	*1*	*2*	*1*	*2*	*1*	*2*
Average (bps)	2.7M	1.7M	2.0M	1.2M	252K	139K
SAR	0.4	0.2	0.4	0.3	0.3	0.3
PAR	3.4	3.1	2.5	2.6	1.8	1.9

Note: SAR = standard deviation to average ratio.
PAR = Peak to average ratio.

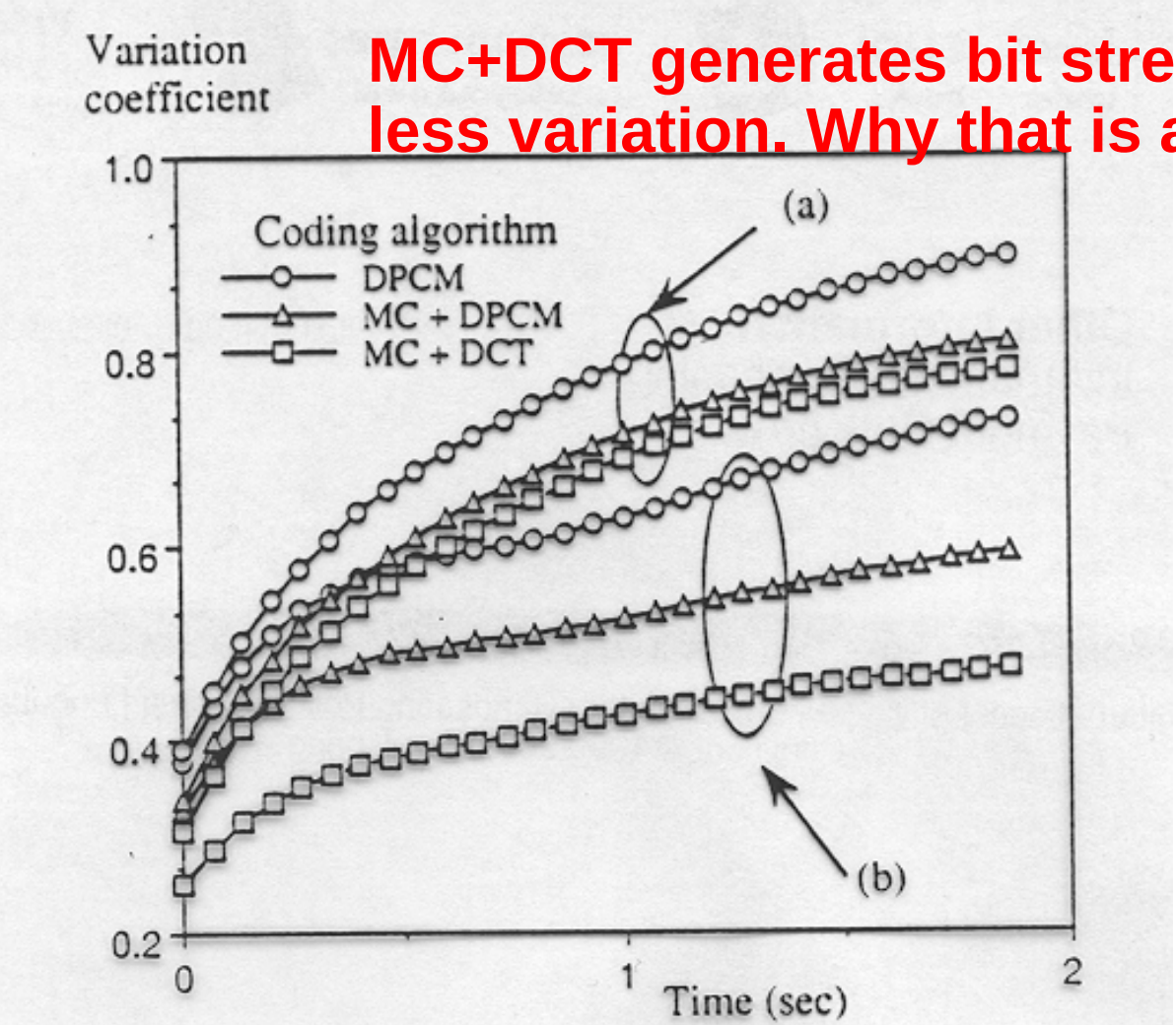


(a)



(b)

Comparison of Encoding Scheme



MC+DCT generates bit streams that have less variation. Why that is a good thing?