

Video

October 16, 2001

Event-based programs

- `read()` is blocking \implies server only works with single socket \leftrightarrow audio, network input
- need I/O multiplexing \implies event-based programming
- also need to handle time-outs, connection requests
- all events (mouse clicks, windows, etc.) handled by event loop
- **do**
 - wait for event(s)
 - handle event (hopefully short)
- **forever**
- harder to maintain state, recursion
- alternative 1: “interrupts” (signals) \implies called at any time
- alternative 2: threads (separate scheduling, same address space)

October 16, 2001

Multiplexing with `select()`

```
int select(int nfd, fd_set *readfds, fd_set *writefds,
          fd_set *exceptfds, struct timeval *timeout)
```

- block until ≥ 1 file descriptors have something to be read, written, or an exception, or timeout
- set bit mask for descriptors to watch using `FD_SET`
- returns with bits for ready descriptors set \implies check with `FD_ISSET`
- cannot specify amount of data ready

October 16, 2001

Audio timing

Need to write block of audio to speaker every t ms ($t = 20 \dots 100$ ms) \implies

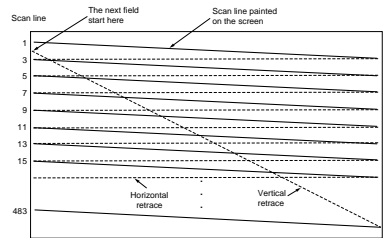
1. timer \implies
 - OS overhead
 - may not be accurate
 - error accumulation (time between timers)
 - clock may differ from audio sampling clock
2. use audio input: for every block read, write one audio block \implies stay in sync
3. but: doesn't work for half-duplex audio cards

October 16, 2001

Analog video

- black & white (RS170) + color burst subcarrier
- 15,750 Hz horizontal scanning

system	where	lines (disp.)	size	f/s	bw
NTSC	US, Japan	525 (483)	4:3	30	6 MHz
PAL	Europe	625 (576)	4:3	25	8 MHz



reduce flicker \Rightarrow interlace scanning: 2 fields/frame

October 16, 2001

Digital video

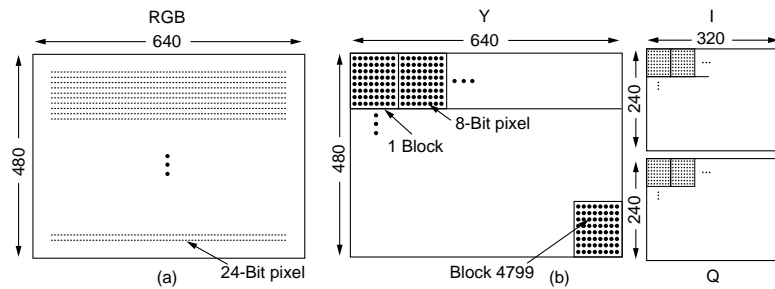
format	lines	pixels
SCIF	480	704
CIF	288	352
QCIF	144	176

- motion video: 5 to 30 f/s
- camera \Rightarrow Red, Green, Blue \Rightarrow chrominance, luminance
- YUV: Y = luminance, UV: color difference (red, blue - Y)

October 16, 2001

Digital video

eye more sensitive to luminance \Rightarrow subsample chrominance: 2:1:1, 4:1:1, 4:2:2



treat chrominance and luminance differently

October 16, 2001

Video coding

lossless (entropy): (X ray images!) run-length, statistical encoding (Huffman coding, ...)

lossy: \Rightarrow exploit spatial redundancy

transform: \rightarrow frequency domain, higher quantization steps for higher frequencies

vector quantization: map $N \times N$ block into N^2 -dimensional space and find closest in *codebook*

model-based: geometric description \Rightarrow very low bit-rate

October 16, 2001

Images

X-ray digitization: 4000 pixels x 4000 lines, at 12 bits/pixel

slide: 120-150 dpi for 6.75" x 10.25"

70 mm movie: 2210 lines

35 mm film: 1753 lines

slide film: 100 lines/mm (2500 lines/inch)

HDTV: 1125 lines

fax: 200 lines/inch

Video coding: JPEG (Joint Photographic Experts Group)

- individual (still) pictures
- lossless or lossy
- typically about 2 Mb/s for video stream
- discrete cosine transform (DCT): samples \mapsto blocks (16x16 Y, 8x8 UV) \mapsto frequency domain 2D matrix, (0,0) = "DC"

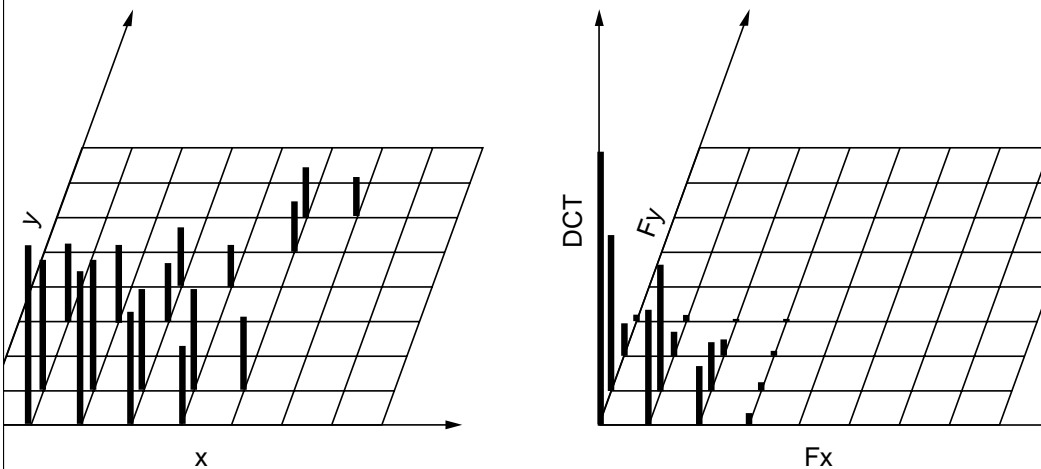
$$B_{u,v}(i, j) = \cos\left(\frac{(2i+1)u\pi}{16}\right) \cos\left(\frac{(2j+1)v\pi}{16}\right)$$

with the transformed image

$$F(u, v) = \frac{2}{N} C(u) C(v) \sum_{i=0}^7 \sum_{j=0}^7 f(i, j) B_{u,v}(i, j)$$

Video coding: JPEG

code frequency sampled with different resolution Q



Video coding: JPEG (Joint Photographic Experts Group)

DC or average (0,0) value: difference to previous block

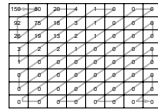
DCT Coefficients								Quantized coefficients							
150	80	40	14	4	2	1	0	150	80	20	4	1	0	0	0
92	75	36	10	6	1	0	0	92	75	18	3	1	0	0	0
52	38	26	8	7	4	0	0	26	19	13	2	1	0	0	0
12	8	6	4	2	1	0	0	3	2	2	1	0	0	0	0
4	3	2	0	0	0	0	0	1	0	0	0	0	0	0	0
2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Quantization table

1	1	2	4	8	16	32	64
1	1	2	4	8	16	32	64
2	2	2	4	8	16	32	64
4	4	4	4	8	16	32	64
8	8	8	8	8	16	32	64
16	16	16	16	16	16	32	64
32	32	32	32	32	32	32	64
64	64	64	64	64	64	64	64

JPEG

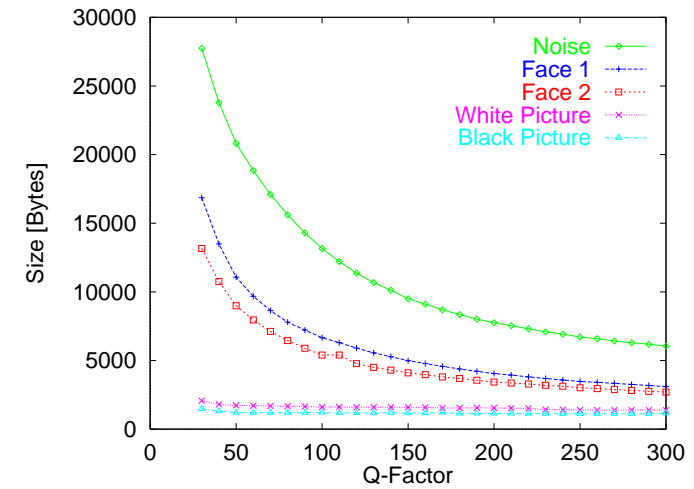
- zig-zag scan:



- run-length coding: group all zeros
- Huffmann coding
- See also <http://www.cs.columbia.edu/~hgs/video>

October 16, 2001

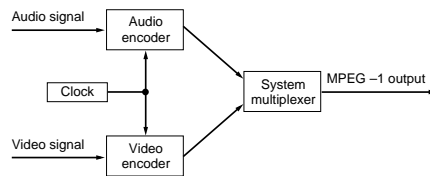
JPEG bandwidth



October 16, 2001

MPEG (Motion Picture Experts Group)

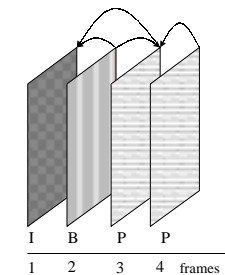
Audio and video:



- \Rightarrow JPEG + motion compensation \approx H.261, MPEG video
- MPEG-1: 1.2 Mb/s fixed rate (CD ROM)
- MPEG-2: higher resolutions (HDTV), scaling
- image prediction: intra (I), forward (P), bidirectional (B) \Rightarrow IBBPBBPBBPBBIBBPBBPB
- need I frames for error resiliency, joining movie in the middle

October 16, 2001

MPEG I, P, B



B frames need to wait for next frame.

October 16, 2001

MPEG: motion compensation



- transmit “motion vectors” to account for panning and zooming \Rightarrow hard to find (must try lots), easy to decode

October 16, 2001

H.261 video codec

- ISDN ($n \times 64$ kb/s) conferencing \rightarrow lower delay
- conditional replenishment: only transmit blocks that are different
- motion vectors for each 16×16 macroblock: ± 15 integer pixels
- GOB: 11 macroblocks H, 3 macroblocks V, marked by *start code*

October 16, 2001

H.263 video codec

- sub-QCIF (128×96), 4CIF (704×576), 16CIF (1408×1152)
- motion prediction outside frame
- advanced prediction mode: 4 vectors for each 8×8 block
- advanced intra prediction – within picture
- slice-structured mode: non-overlapping rectangles
- scalability: temporal (B frames), SNR, spatial

October 16, 2001

HDTV

- subset of MPEG-2 video compression, Dolby AC-3 audio compression
- vestigial sideband modulation (8-VSB) of 19 Mb/s or 16-VSB for two channels in CATV
- formats:
 - 1280 x 720 24, 30, 60 Hz progressive scan
 - 1920 x 1080 24, 30 progressive, 60 Hz interlaced
- MPEG-2 transport stream: fixed-length 188-byte packets (4x47 ATM cells)
- one channel = one or more programs

October 16, 2001

Multiplexing

Pack multiple streams into a single lower layer

- IETF: MIME, RTP (later)
- ITU: H.221 (synchronous, 80x8)
- MPEG: elementary, transport, program
- file formats: AVI, QuickTime

October 16, 2001

Characteristics of digital audio and video

	audio	video
rate	5.3... 64... 1500 kb/s	0.2... 1.5... 19 Mb/s
loss tolerance	$\leq 5\%$	$10^{-5} \dots 10\%$
packet size	small	large
traffic	constant + silences	variable bit rate

October 16, 2001

Audio traffic models

talkspurt: constant bit rate: one packet every 20... 100 ms \Rightarrow mean: 1.67 s

silence period: usually none (maybe transmit background noise value) \Rightarrow 1.34 s

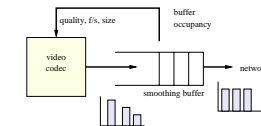
\Rightarrow for telephone conversation, both roughly exponentially distributed

- double talk for “hand-off”
- may vary between conversations... \Rightarrow only in aggregate

October 16, 2001

Video traffic models

- easy case: fit into constant bit rate



- alternative: variable rate \Rightarrow mux gain of $\approx 2 \dots 6$
- short time scales: packets within slice or frame
- medium time scales: I, B, P packet pattern
- longer time scales: scene changes (every few seconds) \Rightarrow higher rate
- looks similar at all time scales, long-term correlation, *heavy-tailed distribution* \Rightarrow *self-similar*
- but: for short queues, long-term correlations don't matter

October 16, 2001