Video technology

- Video signal
- Camera sensors
- Color systems
- Color-TV
- Equipment

Video signal

- Video camera scans the image by following the raster pattern
- Scanning starts from upper left corner and continues according to horizontal lines

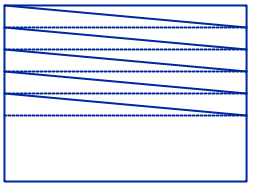


Image ratio

- Image ratio means the horizontal distance ratio to vertical distance
- In standard television, the image ratio is 4:3
- In widescreen television, the image ratio is 16:9

Synchronization

- The synchronization of the raster pattern is made with separate synchronization pulses
- The synchronization requires both horizontal and vertical synchronization pulses
- Synchronization pulses can be attached to the video signal or they can be separate

Resolution

- Resolution means the capability of the television to repeat details
- Horizontal resolution means the capability of single line to repeat distinctive dots
- The amount of individual dots depends on the size of the scanning dot
- Resolution is measured by counting the amount repeating white and black vertical lines

Resolution (cont.)

- Repeating white and black lines cause a high-frequency signal
- In practice, 80 lines equals 1 MHz
- In NTSC standard the bandwidth is 4,5 MHz
  + thus the horizontal resolution is 360 lines
- Vertical resolution depends on the amount of scanned lines
  + in USA, there are 525 lines, while in Europe 625
  + about 40 lines are used, while moving the scanning dot

Frame frequency

- Moving image requires several frames per second
- Common frequency is 25 or 30 frames / second
- 50 frames / second are required to prevent flickering
- The trick is to use interleaving of frames
- First, all odd lines are sent, and after that all even
- The human eye does not detect small flickering objects and thus flickering is not visible

Frame frequency (cont.)

- Interleaving causes unfortunately errors
- A saw tooth shape is visible in fast moving objects
- Flickering is visible in sharp horizontal edges and lines
- Horizontal edges and lines are very common in computer graphics

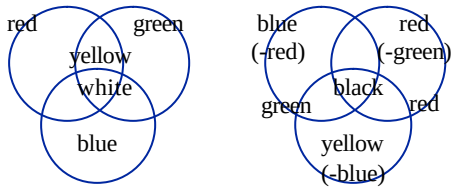
Camera sensors

- In real life, scanning dot is not used in cameras
- The contrast is better, if the light from individual dots is sensored continuously (integration)
- Light increases the voltage on the surface of a light sensitive material
- The voltage level is read using the scanning principle
- Cameras based on both on vacuum tubes and semiconductors are used

Color systems

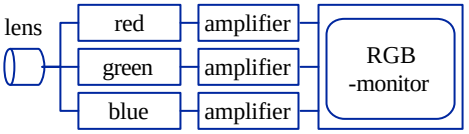
- Color-TV is based on principle, that each color can be presented as a sum of three basic colors
- Subtraction: blue-red, red-green, and yellow
- Summation: red, blue, and green
- Television uses summation while movies use subtraction

Summation and subtraction



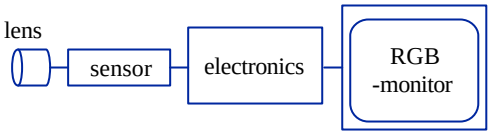
Color-TV

- Color-TV is based on summation
- Light is filtered by three sensors



One sensor

- One sensor system is easier to implement
- Light is divided to different color components
- The division is done by using electronics
- In practice, the resolution is lower



Composite signal

- The transmission of three different color signals is difficult, and thus composite format is often used
- Developed primarily of TV transmission, but is also used in storage, etc.
- Color is divided into luminance (monochrome) and chrome (color) signals
- Signals are created by using matrix transformation

Composite signal (cont.)

- Luminance is transmitted on base frequency, while chrome signals use higher frequencies
- Errors are not visible, because
  - + luminance signal is not sensitive to disturbances especially, if the base frequency of the chrome signal is odd multiply of the half base frequency
  - + eye is much more sensitive to black and white edges than to color edges
  - + thus the frequency band chrome signals can be 2-4 times narrower than he band of luminance signal

NTSC

- North America, Japan, etc.
- National Television Systems Committee, 1950
- Compatible with old black and white TV
  - + only luminance signal is used, while chrome signals are filtered automatically
- Luminance Y (4,5 Mhz) and chrome I (1,5 Mhz) and chrome Q (0,5 MHz)
- Two phase amplitude modulation
  - + I in-phase and Q quadrature (90 phase difference)

PAL & SECAM

- Phase Alternating Line (PAL)
  - + both chrome signals U and V have same bandwidth
- Sequentel Couleur avec Memoire (SECAM)
  - + chrome signals are on alternating lines (FM modulation)
- Conversions between different formats are used

Equipment

- The markets are big, thus there are all kind of equipment
- The equipment can be divided into three categories
  - + studio: big TV companies, etc.
  - + professional: small companies, education, industry, etc.
  - + consumer: home users

Color cameras

- Studio cameras are usually based on three sensors
- Several lenses are available (close, wide, zoom, etc.)
- In addition, smaller portable cameras
- Also, professional cameras use three sensors, but they are simpler
- Consumer cameras have one sensor and also recorder

Movie cameras

- Special film cameras are used for movies
- Movies have usually 24 images / second
- In 25 Hz system, faster speed is used (4 % increase)
- In 30 Hz system, half images (frames) are shown alternatively three and two times
  + ratio become 2:2.5 = 24:30
  + this creates errors (e.g., wheels of a car spin to wrong direction)

Movie cameras (cont.)

- Another problem is the color systems
- Television is based summation, while movies are based on subtraction
- In television, bright colors are best
- In movies, dark colors are best
- Gamma correction, better signal to noise ratio and color processing is required

Recorders

- FM-modulation is used, because magnetic tapes are non-linear
- Usually, films are composed of individual shots and SMPTE code is added to the tape
- Master tape is edited from the shots, and copies are made from it
- Usually, composite signal is used, but components can be also stored separately
- Digital storage improves quality

Recorders (cont.)

- C type: 1 inch open reel (composite; studio)
  + B type in Europe
- Betacam and M II type: 1/2 inch cassette (component; studio)
- U-Matic: 3/4 inch cassette (luminance and chrome signals reordered; professional)
- S-VHS and Hi-8: cassette (component; professional)
- VHS and 8-mm: cassette (as U-Matic; home)

Monitors

- Both image and signal monitors
- Studio quality monitors are matched
- Professional monitors are cheaper
- In home, television is used (receiver + monitor)
- SCART interface allows also the use of composite and RGB (component) signals

Video compression

- Properties of compression systems
- Basics of video compression
- Methods
- Algorithms
  + H.261
  + MPEG-1
  + MPEG-2
  + MPEG-4
  + MPEG-7

Compression ratio

- Ratio of unprocessed and compressed data
  + 512 x 480 x 24 = 737 280 B
  + 737 280 B / 15 000 B = 49
- Resolution and amount of colors can change
  + 256 x 240 x 24 = 184 320 B
  + 184 320 B / 15 000 B = 12,29
- Bits per pixel (bpp) is much better measure
  + (15 000 x 8) / (256 x 240) = 1,95 bits per pixel (bpp)

Image quality

- Lossless and lossy compression
- More efficient coding methods are used in lossless compression
- In lossy compression, the content of an image changes
- Can create all kinds of errors
- Image quality is hard to define

Compression speed

- Usually compression and decompression are separate processed done at different times
- Often image or video is compressed once and decompressed several times
- Then, compression can take long time, while decompression has to be fast
- In video conferencing, the situation is different

Hardware or software

- Some algorithms can be implemented as software, but certain methods require hardware implementation
- Hardware can be general or designed especially for certain algorithm
- Special purpose hardware cannot be changed, but it is usually much faster

Basics of video compression

- Images have a lot of redundant information
  + neighboring pixels have often same color
  + in horizontal objects individual lines are often similar
  + stationary of slowly moving objects are same on the following images
- Viewer does not see all details
  + eye is not very sensitive, e.g., to colors

Methods

- Introduction
- Simple methods
- Interpolation
- Prediction
- Transformation
- Statistical methods
- Motion compensation

Introduction

- Video compression is much researched area
- Some methods require a lot of computation
- Typical compression method uses several techniques

Simple:	**Inter-polative:**	**Predictive:**	**Transform:**	**Statistical:**
Truncation CLUT Run-Length	Subsample	DPCM Motion compen-sation	DCT	Huffman

Simple methods

- Color resolution can be easily dropped to 16 bpp
- Another alternative is to use color table
  + Color Lookup Table (CLUT)
  + 8 bpp acceptable quality
- In addition, run-length coding can be used
  + repeating colors are replaced by code, which tells the color value and the amount of repeating pixels
  + in computer graphics, animations and CLUT coded images less than 1 bpp can be achieved

Interpolation

- Only some pixels are coded, while rest are interpolated
- In practice, this means lower resolution
- Works well in coding of color components (subcoding)
  + every fourth sample is take both in horizontal and vertical direction from the Y and U components (1/16)
  + 8 bpp + (8 bpp + 8 bpp) / 16 = 9 bpp
  + does not work in synthetic image

Prediction

- Can be used to predict next pixel, line, or image
- DPCM: only difference between following samples is coded
  + uses less bits per sample; overflows are a problem
- ADPCM: step size can be changed
  + requires extra bits
- The problem in prediction is repetition of errors
- Usually used in combination with other methods

Transformation

- Data is transformed into another form
- Requires also inverse transformation
  + X_0 (8 bit) & others 4 bit: 8 b + 3 x 4 b = 20 b (5 bpp)

A	B
C	D

X_0	X_1
X_2	X_3

Transform:	Inverse transform:
$X_0=A$	$A=X_0$
$X_1=B-A$	$B=X_1+X_0$
$X_2=C-A$	$C=X_2+X_0$
$X_3=D-A$	$D=X_3+X_0$

DCT Transform

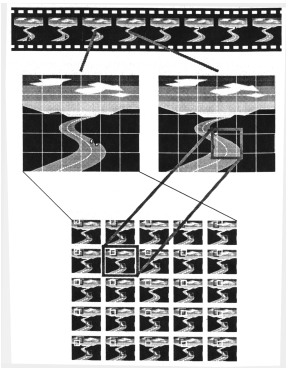
- Discrete Cosine Transformation (DCT) is most common transformation
- Group of pixels are transformed into coefficients of basic frequencies
- First, zero frequency is called DC coefficient
- Most coefficients are very small or even zero
- Coefficients are quantized to certain accuracy

Statistical methods

- Usually both original and coded images have statistical bias
- Common values are coded with short codes, while longer codes are used for less common values
- A codebook is required, which has to be sent to the receiver
- The sending frequency of the code book can be controlled

Motion compensation

- In video, following images has much redundancy
- The problem is to find the areas which change and extract them form the image
- The solution is to divide the image into block and code only the blocks, which have changed
- In addition, the movement of the blocks can be coded



Algorithms

- Usually, a compression algorithm uses several compression methods
- Algorithms are defined as standards
- International Organization for Standardization ISO International Electrotechnical Commission IEC
  - + Joint Photographic Expert Group (JPEG)
  - + Motion Picture Expert Group (MPEG)
- International Telecommunications Union (ITU)

H.261

- Original video (625 or 525 lines) is transformed into CIF format
- Bit stream contains all necessary information and it can multiplexed with audio
- Bit stream is 40 kbps - 2 Mbps
- Both uni- and bi-directional communication
- Error correction
- Multipoint conferencing

CIF format

- Luminance - Chrominance (Y, CB, CR)
- 8 bits / sample
- 30 frames / second
- Luminance 352 x 288 resolution
- Chrominance 172 x 144 resolution
- Quarter-CIF format divides the resolution into half
- All coders/decoders support QCIF format
- CIF format is optional

Coding algorithm

- H.261 uses image prediction and DCT transformation
- In INTRA mode, image is coded alone, while INTER mode uses prediction
- Image is divided into 16 x 16 macroblock, which contain four 8 x 8 luminance blocks and two 8 x 8 chrominance blocks
- In addition, block groups are used
- 0, 1, 2, or 3 images can be dropped

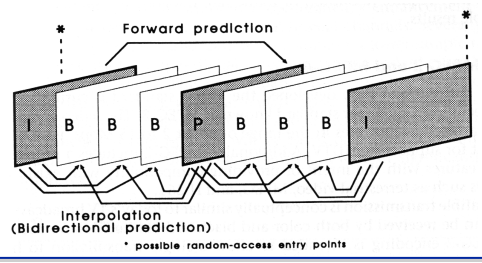
MPEG

- Good image quality 1,0 - 1,5 Mbps
- Symmetric or asymmetric coding/decoding
- Repeat from any point possible
- Rewind and backward repeat possible
- Audio/video synchronization
- Data errors should not create problems
- Compression /decompression delay control
- Editing is possible
- Different formats (windows)
- Cheap circuits possible

Architecture

- Four image types
  - + I images are independent (coded separately)
  - + P images are predicted from other I and P images
  - + B images are interpolated both from previous and following I or P images
  - + D images are for fast searching
- I images takes most space; P image 3:1; B images further 2-5:1
- Decoding of B images creates delay

MPEG image sequence



Bitstream syntax

- MPEG Bitstream is composed of several layers:
  - + video sequence (complete sequence)
  - + image sequence (all parameters; seek)
  - + image (individual image)
  - + subimage (contain synchronization etc. information)
  - + macro block (16 x 16; image compensation)
  - + block (8 x 8)

Efficiency

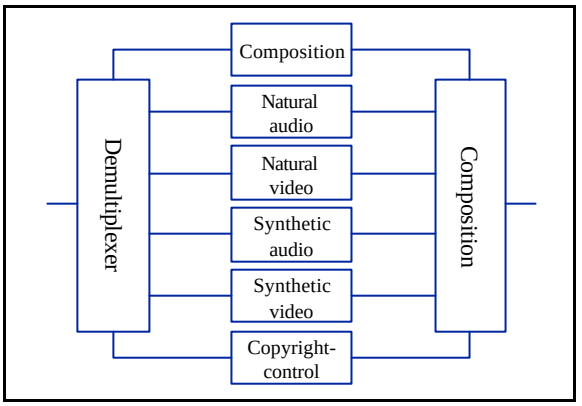
- Different resolutions and bit rates can be used
- E.g., CD-ROM 30 frames / second, 352 x 240 resolution (same as VHS recorder)
- Both compression and decompression can be done by software
- Real-time compression requires hardware, though

MPEG-2

- MPEG-2: bit rate 2 - 15 Mbps
- Allows also high-definition TV
- Used in digital television
- Five audio channels, base and seven language channels
- Video, audio, and data streams are composed as one transport stream

MPEG-4

- MPEG-4: low bit rates
- Video and audio can be decomposed into components
- Different compression methods can be used for different components
- Introduction of new coding methods is possible



MPEG-7

- MPEG-7 is not a compression standard, but rather it is intended for content description
  - + multimedia content description
  - + flexibility in content management
  - + interfacing different data sources
- That is, MPEG-7 is a metadata standard
- Can be used for content retrieval and filtering