Lab „Platforms for Embedded Systems“
Chapter 04: Video

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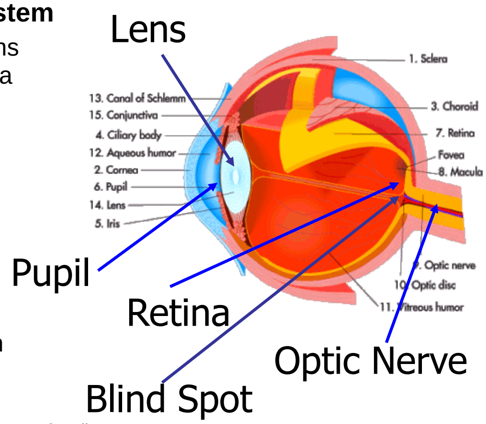
- **Recap: Digital / Compressed Audio**
  - Example of an application domain for embedded plattforms: „Multimedia“
  - Core functionalities of Mobile Multimedia Systems (MMS)
  - The basics: sampling rate and bit-width
  - The mathematics: creating our own sound waves
  - Multimedia UseCases and Filtergraph Architectures
  - Example: GStreamer

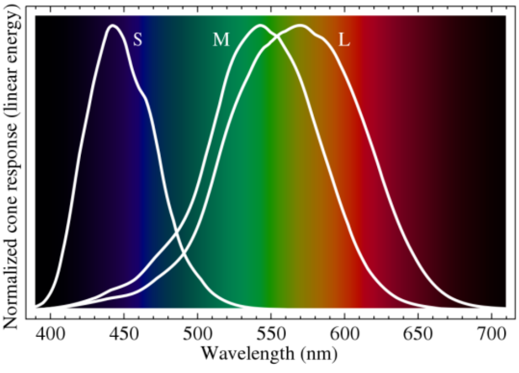
- **Goals of this Chapter:**
  - Some Basics to understand digital Video:
    - HVS: Human Visual System
    - Color Spaces and Color Compression
    - MPEG Compression
    - A/V multiplexing and synchronisation
  - Video using GStreamer

- **Overview**
  - HSV and Color Spaces
  - Color Compression and Subsampling
  - MPEG: Motion Picture Expert Group
  - Video Filter Graphs using GStreamer

- **Overview: Digital Video**
  - **HVS: Human Visual System**
  - Light passes through the lens and is focussed on the retina
  - **Retina** is built of:
    - **Cones** – sensitive for color (chrominance), mostly in the center of the retina (fovea)
    - **Rods** – very(!) sensitive for brightness, i.e. B/W (luminance) and for move-ments, but lower resolution
  - Electrical signals from the retina to the visual cortex in the brain. There the „preprocessing“ takes place (filtering, edge detection, object detection).

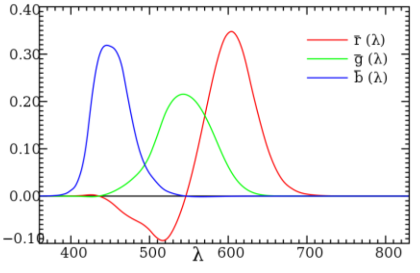


- **Overview: Digital Video**
  - **HVS: Human Visual System**
  - Cones are used to convert the wavelength of the light into three values („tri-stimulus“)
  - tri-stimulus values encode the relative signal strength of the three bas colors.
  - Different colors are represented by differente combinations of tri-stimulus values.



Overview: CIE RGB Color Space

- Tries to „simulate“ the Human Visual System
- Defines three base colors R, G, B
  - CIE RGB red = 700 nm, green = 546.1 nm, blue = 435.8 nm
- Maps monochromatic light (single color) to RGB triplets
  - Many statistical experiments required, since different persons have slightly different perception of colors



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Overview: YUV Color Space

- **Convention:**
  for transmitting signals for Color-TV, a different Tri-Stimulus is applied: YUV
- Informatin is separated into:
  - Y: 1 x luminance value, and
  - UV: 2 x chrominance values
- **Reason:**
  Color-TV should be backward compatible to B/W-TV, i.e. the signal has to contain the regular B/W information → Y component
- **Transformation** (PAL system):
  - $Y=0.3R+0.6G+0.1B$
  - $U=0.5(B-Y)$
  - $V=0.625(R-Y)$
  - Note: the higher weight of the green component refers to the high sensitivity of the HSV for green colors.

- **Overview**
  - HSV and Color Spaces
  - Color Compression and Subsampling
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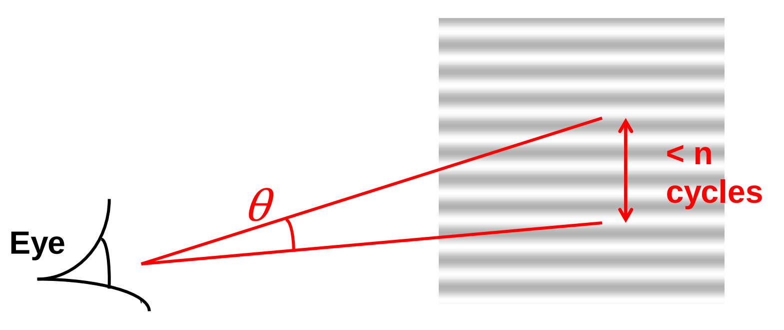
- **Digital Video: Color Compression (1/6)**
  - Additional property of the HSV:
    limited capability to discriminate and detect „many changes of color“ on limited space (Spatial Frequency Sensitivity)
  - JPEG / MPEG heavily relies on the property to reduce the amount of data



- **Digital Video: Color Compression (2/6)**
  - Original Image (YUV): 512 x 512 x 3 (values for Y, U, V)

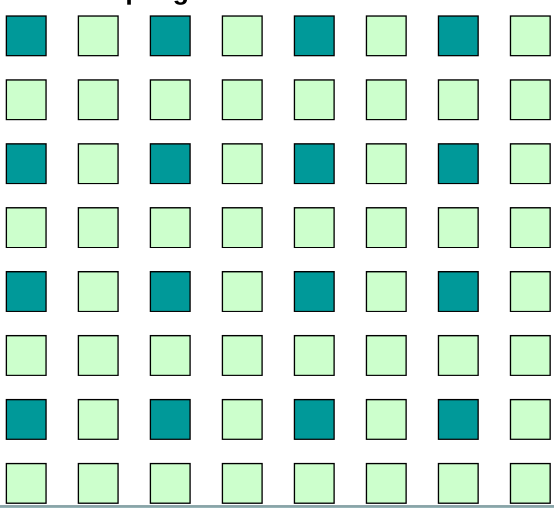
- **Digital Video: Color Compression (3/6)**
  - **Color Plane Subsampling**

Keep Discard

2:1 in both directions

Y channel:
NO compression

U, V channels:
Downsampling in X and Y dimension



- **Digital Video: Color Compression (4/6)**
  - **4:1 Color Downsampling:** 512 x 512 + 256 x 256 x 2
  - Results in 50% data size

- **Digital Video: Color Compression (5/6)**
  - **16:1 Color-Downsampling**: 512 x 512 + 128 x 128 x 2
  - Results in 33% data size

- **Digital Video: Color Compression (6/6)**
  - **+ additional 16:1 Downsampling of the luminance value**: 128 x 128 x 3 (1/16th of the original data size)

- **Overview**
  - HSV and Color Spaces
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- **Overview: Motion Picture Expert Group (MPEG)**
  - **MPEG1:** 320x240 pixel resolution @ 30 frames per second. Used for initial video on PCs
  - **MPEG2:** higher resolutions compared to MPEG1, mainly used in digital TV and DVD. Streaming possible!
  - **MPEG3**: originally planned for HDTV; later was merged into MPEG2
  - **MPEG4**: Object based approach to converge digital video, computer animations and Internet (e.g. BIFS standard: Binary Format for Scenes)
  - Why not simply use JPEG format?

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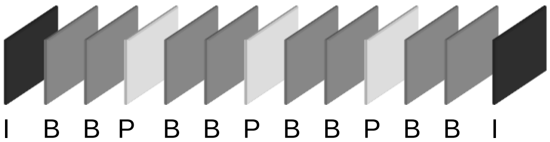
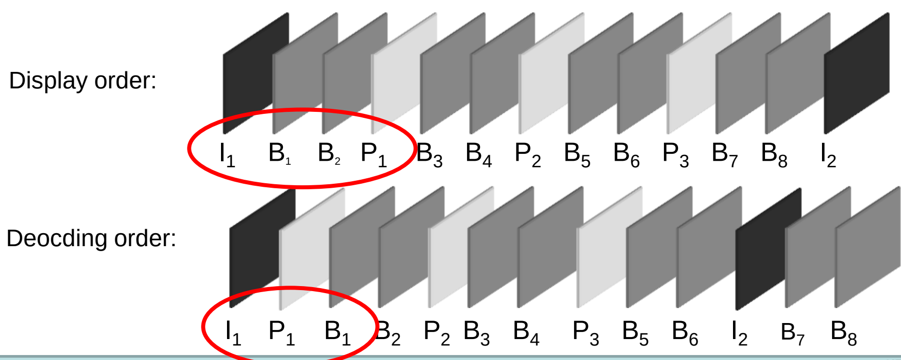
- **Digital Video: MPEG**
  - Based on YUV color space
  - 8 bits per pixel and channel
  - Uses (2:1:1)-Downsampling:
    - Luminance: full resolution, i.e. 320 x 240
    - Chrominance: ¼ resolution, i.e. 160 x 120
  - Separation into macro blocks:
    - 16x16 pixel used for luminance
    - 8x8 pixel for each chrominance component
    - required for motion estimation

- **MPEG: Structure of MPEG Format (1)**
  - **MPEG: Group-Of-Pictures (GOP)**
  - **Intraframe Coding (I)**: encode complete frame, similar to JPEG
  - **Predictive Frames (P)**: only difference between current frame and previous frame gets encoded
  - **Bi-directional frames (B):** differences between previous AND between following frames get encoded
  - GOP: usually, up to 12 B / P frames between 2 I frames

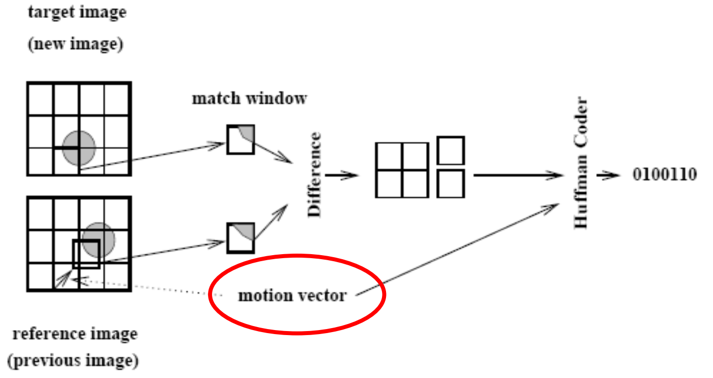


- **MPEG: Structure of MPEG Format (2)**
  - **MPEG: Group-Of-Pictures (GOP)**
  - Results in different sequences of decoding and displaying frames
  - This increases the memory size required to temporarily keep frames



MPEG: Motion Estimation in MPEG

- **Idea:** reuse macro blocks where content has been slightly moved between previous and current frame

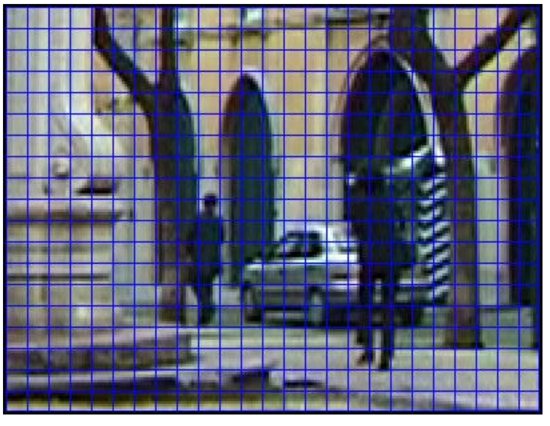


Digital Video: Motion Estimation (1/7)

- **Challenge:** how to find/calculate motion vectors
- Example: 1st Frame (I-Frame)

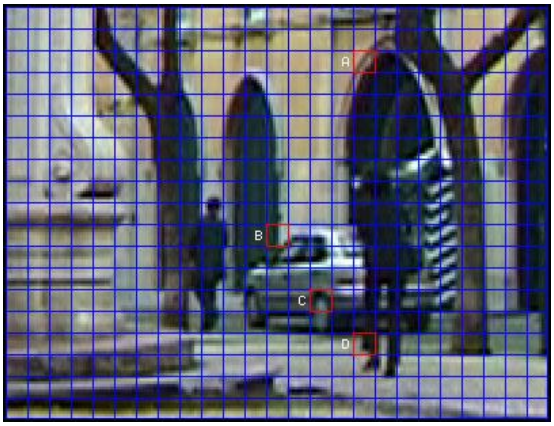
- **Digital Video: Motion Estimation (2/7)**
  - 2nd Frame: „Which parts of the image have moved?“

- **Digital Video: Motion Estimation (3/7)**
  - 2nd Frame: Separation into Macro Blocks



Digital Video: Motion Estimation (4/7)

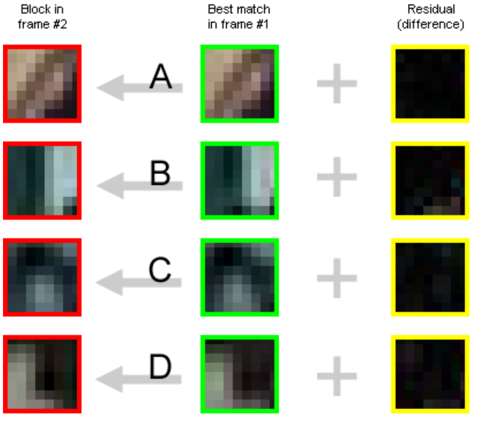
- 2nd Frame: We focus on Macro Blocks A,B,C and D



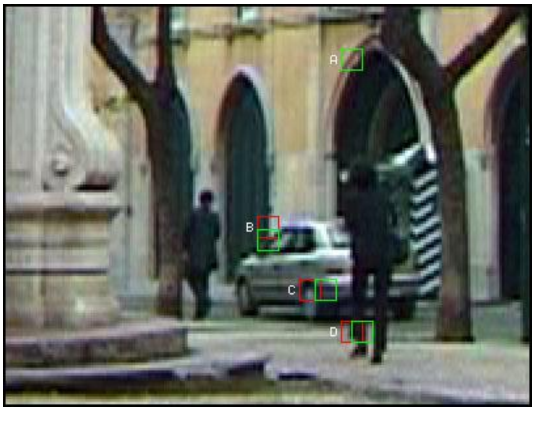
Digital Video: Motion Estimation (5/7)

- Best match in frame 2 for these macro blocks:

- **Digital Video: Motion Estimation (6/7)**
  - Transformation of best-match macro blocks
  - MB(2nd Frame)= MB(1st Frame)+ difference („residual“)



- **Digital Video: Motion Estimation (6/7)**
  - Comparison: Macro Blocks in frame 1 and 2



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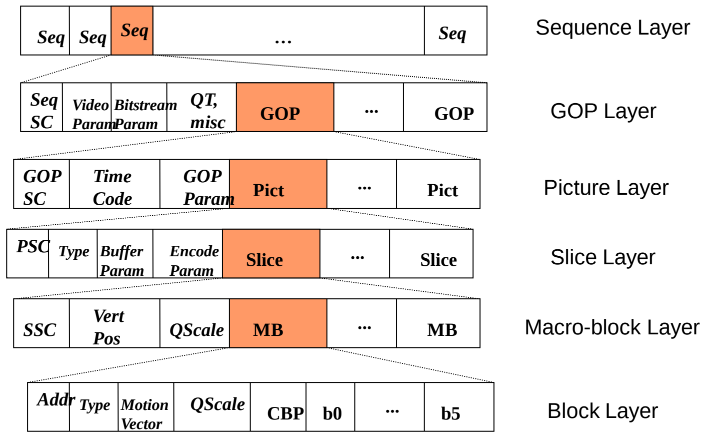
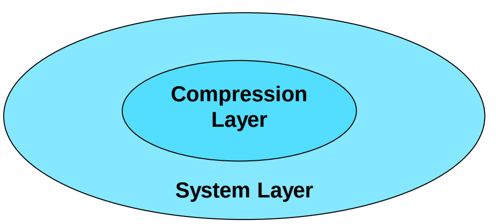
- **Digitales Video: MPEG-1 Interchange Format**



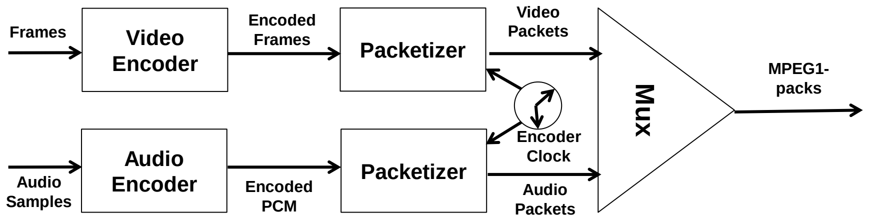
04: Multimedia - Video

- **MPEG 1: Compression und System Layer:**
  - Until now, we only considered the compression of video (and audio)
  - However, end-to-end solution requires additiona functionality



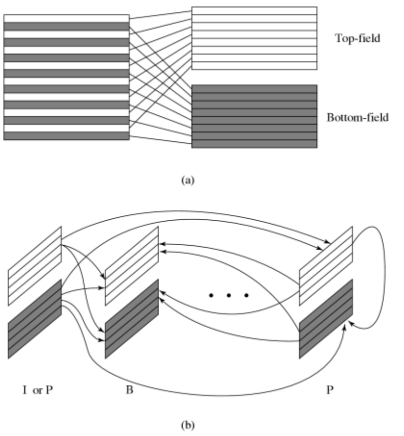
  - System Layer used for add. Functions, such as:
    - „interleaving“ of audio and video content (Multiplexing)
    - synchronisation of different streams

- **Digital Video: A/V-Multiplexing**
  - MPEG2 streams are packetized into 188 Byte chunks → no single frames any longer
  - DTS: Decoding Time-Stamp
  - PTS: Presentation Time-Stamp



- **Digital Video: MPEG2 extensions to MPEG1 (1/2)**
  - Base and „Extension“ layer to improve video quality
  - Scalable encoding fro different bitrates and VBR (variable bit rate)
  - Scalable across time domain → different frame rates
  - Scalable across spacial domain → different frame resolutions
  - Add. Transport stream to correct bit errors during streaming use cases
    Skalierbares Encoding für unterschiedliche Bitraten und VBR (variable bitrate)
  - Non-linear quantization

- **Digital Video: MPEG2 extensions to MPEG1 (2/2)**
  - supports interlaced video (next to progressive video)



- **Overview: Digital Video**
  - **References and add. information:**
    - http://dvd-hq.info
    - http://surendar.chandrabrown.org/teach/spr09/cse40373
    - http://courses.engr.illinois.edu/cs414
    - http://www.mee.tcd.ie/~corrigad/4c8
    - http://cseweb.ucsd.edu/classes/sp03/cse126

- **Digital Video Using GStreamer**
  - Now we are ready for:
    - **Exercise 10 –**
      Video-decoding and playback based
      Gstreamer framework

- **Zusammenfassung „Digitales Video“:**
  - The physiological foundation: Human Visual System
  - The physical background: Color Spaces and Color Compression
  - MPEG Compression
  - Video using GStreamer