# Basics of Video Editing Technology

BFR6032.FK Editing

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#### Illusion of cinema and television

- The illusion of a moving pictures (cinema, television) is possible because of the phenomenon called **persistence of vision**. This means that it takes some time before the image registered in our eye's retina fades away.
- Persistence of vision explains why we do not notice the flickering and the black screen of the cinema projector and TV screens.

## Illusion of the movement

- In year 1912 one of founders of gestalt psychology Max Wertheimer described a phi phenomenon and beta movement.
- Phi phenomenon in a motion perceived by a subject, especially the illusion of movement produced when stationary stimuli, as pictures or lights, are presented in rapid succession and are sometimes in slightly different positions.
- Beta movement is an optical illusion whereby a series of static images on a screen creates the illusion of a smoothly flowing scene.
- Try yourself:
  - <u>http://mesosyn.com/mental8-14.html</u>
  - http://www.michaelbach.de/ot/col-lilacChaser/index.html
  - http://www.michaelbach.de/ot/col-colorPhi/index.html

# Film framerate

- Human brain can differentiate between separate images when there are less than 10-12 images per second.
- Greater framerate creates an illusion of continuous movement.
- As the result of the experiments conducted by Thomas Alva Edison was determined that 46 frames in second was minimum to avoid noticeable flickering.
- 46 frames in second for film stock would be too expensive!
  Another solution was needed...

# Film framerate

- In early silent films the framerate of about 16 frames per second was used.
  - The exact speed was dependent on the camera operator hand movement speed: ca 14-26 fps.
- Together with the sound film the speed was standardized in year 1929 to 24 fps.
- Cinema projector shows one frame several times (flicker rate)
  - I6 fps + every frame 3 times = 48 pictures in seconds
  - 24 fps + every frame 2 times = 48 pictures in seconds

#### Video framerate

To avoid image flickering and minimize the frequency band required for television transmission in beginning of 1930-s the interlaced scanning was developed.

In Europe 50Hz and in USA 60Hz system was implemented:
 50/60 fields in second = 25/30 frames in second

# Interlaced scanning

One frame on interlaced scan video is created from 2 fields (odd and even field)

Odd scan lines Even scan lines

Each field is displayed for 1/50th of second (in PAL) producing 25 frames per second

#### Progressive scanning

Progressive scan means drawing the odd and even scan lines in order without interlacing.



One complete frame, 25 frames per second (in PAL)

#### Birth of color television

When color television was launched video standard was created that would be backward compatible with the black and white video signal.

Video signal was divided into two parts:

- Iuminance (black & white part of the image) amplitude of the gray scale
- chrominance (color information) saturation and hue characteristics

#### International televisioon standards

- PAL (phase alternate line) The European standard for color television transmission, has 625 scanlines, scanned at a rate of 25 frames per second
  Operate at 50 Hz
- SECAM (Sequential Colour a Memoire) a TV standard developed by the French and used in France, Russia and other countries (625 scanlines, 25 frames per second)
- NTSC (National Television standards Commitee) The U.S. Standard for color TV transmission, has 525 scanlines, scanned at a rate of 30 frames per second (to be exact 29.97 frames per second)
- Operate at 60 Hz

#### International digital television standards

 DVB (Digital Video Broadcasting) – Digital television standard used in Europe

- DVB-S (satellite TV)
- DVB-C (cable TV)
- DVB-T (terrestrial TV)

 ATSC (Advanced Television Systems Committee) - Digital television standard used in USA

#### Moviola editing table



http://www.manueliglesias.com/images\_taller\_montaje/moviola.jpg

#### Steenbeck 35mm editing table



http://www.koelner-filmhaus.de/05\_06-technik-schnitt.htm





http://www.cinemax.jp/products/film\_edit.html

# Film editing













#### Film edge numbers - keycode



http://en.wikipedia.org/wiki/Keykode

# History of video editing



Figure 3.14E. RCA Kinephoto Equipment. Courtesy RCA.

Kinescope – a recording of a television program made by filming the picture from a video monitor.
 Film stock was very expensive.

Another solution was needed.

#### First videotape recorder



■ 1956 AMPEX Ampex VR-1000 2-inch videotape recorder

# History of video editing

- The videotape recording process was first demonstrated in 1953, and the first machines went into service in 1956
- I956 AMPEX 2-inch videotape recorder
- In late 1950-s SLICE and SPLICE editing
- Beginning of 1960-s Electronic editing devices were developed
- 1967 Time-Code based Editing

# Linear editing system





#### Editing controller

Structure diagram of dual-post editing linear system with two VTRs and one controller

http://eng.625-net.ru/content/2004\_08/prodsys7.htm

## Structure of videotape



#### Control track and timecode

- Control track an electronic signal recorded on videotape at each head revolution and each field that tells the next machine how to play back that particular video signal. Similar in concept to the sprocket holes in film
- TIME-CODE Electronic indexing method used for editing and timing video programs. Timecode is a label that uniquely identifies each frame of video expressed as hh:mm:ss:ff
- SMPTE (Society of Motion Picture and Television Engineers) time code -Binary time code denoting hours, minutes, seconds and frames.
- Be careful with the timecode breaks!

#### Use of timecode

- PRESETS it is possible to set the start of the timecode in the camera, and in VTR's
- Every memory card could start with new hour of timecode (first starts 01:00:00:00, second 02:00:00 etc.)
- In finished master the program starts at timecode **10:00:00:00**
- REC RUN timecode "runs" only when recording (usual practice)
  FREE RUN timecode "runs" constantly (usually used "time of the day") useful for multicamera setups or dual system audio recording

#### Human eye



- There are about 120 million rod cells (react for brightness) and 6 million cone cells (react for color) in human retina.
- Human eye is more sensitive for brightness than for the color.
- In low light condition human eye sees in black and white.

## Breaking up white light in the prism



http://www.risk.net/IMG/847/94847/light-split-into-spectrum-by-prism.jpg

#### Human eye's relative color sensitivity based on the wavelength of the light



### Additive and subtractive color model



http://academics.wellesley.edu/Neuroscience/Neuro320/Coursecontent/colorbasics.html

#### Additive and subtractive color model

#### Color Mixture

http://www.michaelbach.de/ot/col\_mix/index.html

- Color Matching Game
  - http://www.michaelbach.de/ot/col-match/index.html

#### Video camera and monitor



- The image is turned upside down in the lens, registered as pixels in the camera light sensitive sensor (CCD or CMOS)
- Video signal is transformed back into pixels in the monitor screen that recreates the captured image.

Ascher, Steven & Pincus Edward. The Filmmaker's Handbook. A Comprehensive Guide for the Digital Age. 4th ed. Plume 2013.

# Splitting the color image into three components inside the 3 CCD camera (RGB)



 $Y = 0.299 R + 0.587 G + 0.114 B \quad (in PAL)$
### **CCD** - Charge-Coupled Device



An array of light sensitive elements. Light is converted to an electrical charge in a linear fashion – proportional to the brightness impinging on each cell. The cells are coupled to a scanning system which, after analog to digital conversion, presents the image as a series of binary digits.

### **CMOS - Complementary Metal-Oxide Semiconductor**



The chips are cheaper than the alternative CCDs, they consume less power, can be more sensitive (faster), have less image lag and can include image-processing functions on the sensor chip.

https://martinmoorephotography.files.wordpress.com/2012/01/k-r-cmos-sensor.jpg

## CCD vs CMOS



http://meroli.web.cern.ch/meroli/lecture\_cmos\_vs\_ccd\_pixel\_sensor.html

 CCDs move photogenerated charge from pixel to pixel and convert it to voltage at an output node.

 CMOS imagers convert charge to voltage inside each pixel.

#### Read more:

- Filmmaker IQ "The Science of Camera SensorsThe Science of Camera Sensors"
- <u>http://meroli.web.cern.ch/meroli/lecture\_cmo</u> <u>s\_vs\_ccd\_pixel\_sensor.html</u>

### Rolling Shutter defect

CMOS sensors that use Rolling Shutter can have special looking defects

- This is mostly visible in high speed movement and straight lines
- Global Shutter CMOS sensors do not suffer from this defect.

#### Look more:

- <u>https://www.red.com/red-101/global-rolling-shutter</u>
- <u>http://dvxuser.com/jason/CMOS-CCD/</u>





Color Filter Array Sensor



http://www.dpreview.com/glossary/camera-system/sensors

### Bayer pattern array



Similar to human eye (eye is most sensitive in the green spectrum) the Bayer filter has 2 times more green than red & blue pixels.

> Developed in 1976 by dr. Bryce E. Bayeri (company Eastman Kodak).

#### Read more:

- http://www.cambridgeincolour.com/tutorials/camera-sensors.htm
- https://www.red.com/red-101/bayer-sensor-strategy

http://en.wikipedia.org/wiki/Bayer\_filter

## RAW video





 Cameras that record in RAW format preserve all the data coming from the camera sensor. This allows greater flexibility in post processing and image manipulation in the post production.

#### • To see the RAW image is needed:

- demosaic or debayer calculating RGB values for each pixel (processor intensive)
- fixing of white balance
- fixing of color space (rec 709 for example)

## Composite video signaal



Composite video signal is an analogue signal that combines luminance and chrominance along with the timing reference sync and color burst information One cable needed (BNC or RCA)

http://www.productionapprentice.com/tutorials/general/component-composite-and-digital/

# Y/C or S-video signal



Y/C or S-video signal consists on two seperate parts:

- luminance black and white information
- chrominace color information

Needs one 4-pin cable (S-Video)

http://www.productionapprentice.com/tutorials/general/component-composite-and-digital/

## Component video signal



**Component video signal** uses three separate cables:

- Luminance
  - )
- color difference signals
   R-Y
  - □ **B-**Y

#### Needs three cables (BNC or RCA)

http://www.productionapprentice.com/tutorials/general/component-composite-and-digital/

# Component video signal



- Different sysmbols used for component video:
  Y, R-Y, B-Y
  - YUV
  - Y, Pb, Pr analog component video
  - Y, Cb, Cr digital component video

## Component video



http://en.wikipedia.org/wiki/YCbCr

### Analog videosignal waveform

#### The television waveform



## Waveform monitor – test table



http://educypedia.karadimov.info/electronics/televisioncolor.htm

# Videoscopes



 Videoscopes in Davinci Resolve-s:

- Waveform
- Parade
- Vectorscope
- Histogram

## Analog vs digital signal

- Analog a continuously varying electronic signal. Audio and video analog signals deteriorate with each copy or generation (loss of quality of the signal).
- Digital electronic system which functions by converting the analog signal into a series of discrete binary bits (ones and zeros). The quality of the digital signal does not deteriorate with each copy or generation.

# Analog to digital conversion



Sampled signal

Quantisized signal

ŧ>

**Digital signal** 

# Sampling

- Sampling measuring the analog signal values at specific time intervals (taking samples).
- Sampling rate must be at least 2 times greater than the analog signal's highest frequency component (Nyquist criteria).
- For example CD disk sampling rate 44,1 KHz is a bit higher than two times 20 KHz (the highest frequence human can hear)
- If sampling rate is too low then there will be aliasing sampling artifacts.
- To avoid aliasing defects low pass filter or anti-alias filter is used that removes the not needed high frequencies from the signal.



## Moire pattern



http://en.wikipedia.org/wiki/Aliasing



#### http://en.wikipedia.org/wiki/Aliasing

http://www.red.com/learn/red-101/resolution-aliasing-motion-capture



- Quantization giving numerical value to the sampled signal
- The larger is the scale the more detailed changes in the amplitude of the signal can be described (the smallest is the quantization error)
- Quantization error the difference between the original analog signal and its digital representation.

## Quantization

- Bit depth how many binary bits are used for describing a sampled signal
  - 8 bit =  $2^8$  = 256 discrete levels 10 bit=  $2^{10}$  = 1024 discrete levels 12 bit=  $2^{12}$  = 4096 discrete levels 16 bit=  $2^{16}$  = 65536 discrete levels 20 bit =  $2^{20}$  = 1048576 discrete levels 24 bit =  $2^{24}$  = 16777216 discrete levels
- The higher the bit depth the higher the quality of video or audio but also the amount of data will get larger.

### Binary code

- Bit (short for binary digit) is the smallest unit of digital data. A bit has a single binary value, either 0 or 1.
- Byte a unit of computer information that is equal to eight bits
   I byte (B) = 8 bit (b)

Large amounts of data are described in kilobyte (kB), megabyte (MB), gigabyte (GB), terabyte (TB), petabyte (PB) etc.

Kilobyte can mean 1000 (10<sup>3</sup>) bytes or 1024 (2<sup>10</sup>) bytes.

<u>https://en.wikipedia.org/wiki/Byte</u>

# Digital – analog conversion



### Chroma subsampling

- 4:4:4 Every RGB or Y, Cb, Cr pixel is sampled equally.
   Maximum color information is preserved.
- 4:2:2 Color difference channels (Cb, Cr) are sampled with ½ the sample rate. Half of color information is stored.
- 4:1:1 Color difference channels (Cb, Cr) are sampled with ¼ the sample rate. Quarter of the color information is stored.
- 4:2:0 Similar to 4:1:1. Quarter of the color information is stored.

#### Video chroma subsampling



#### Read more: https://www.red.com/red-101/video-chroma-subsampling

## Digital connections



**Fig. 5-29.** Data and video connectors. (A) USB 2.0 male A connector. (B) USB 2.0 Mini B connector. (C) USB 3.0 male A connector (USB 3.0 is faster than 2.0 but this connector is backward compatible with 2.0 ports). (D) USB 3.0 male B connector. (E) FireWire 800 (IEEE 1394). (F)

FireWire 400 four-pin connector. (G) FireWire 400 six-pin (the two extra pins supply power). (H) DVI connector. (I) HDMI connector. For other

## SDI – serial digital interface



- SDI serial digital interface
   Digital connection over BNC coaxial cable (video and audio)
- HD-SDI used for HD video
- Dual-link HD-SDI
- 3G-SDI
- 6G-SDI
- I2G-SDI

### Picture aspect ratio

#### Aspect Ratio of the Video Frame

The ratio of horizontal to vertical dimensions of a film or video frame is called the *aspect ratio*. Aspect ratio is independent of absolute image size or resolution.



Aspect ratio can be expressed as absolute dimensions  $(4 \times 3)$ , a ratio (4:3), a fraction (4/3), or as the decimal equivalent of a ratio (1.33:1, or simply 1.33).

- Video aspect ratios are often written as ratios, such as 4:3 for SD video or 16:9 for HD video.
- Film aspect ratios are often written as decimal equivalents, such as 1.33, 1.85, and 2.40. The higher the decimal number, the wider the image. An aspect ratio of 2.40 is wider than 1.85, and 1.85 is wider than 1.33.
- Digital video resolutions are usually written as absolute pixel dimensions, such as 720 x 480, 1280 x 720, 1920 x 1080, and so on.

Aspect ratio	Medium
1.33 (4:3)	Early 35 mm film and SD television
1.37	4-perforation 35 mm camera footage (prior to projection)— also known as "Academy" aspect ratio
1.66 (15:9)	Standard European film; masked in projector
1.78 (16:9)	HD television
1.85	Standard North American and UK film; masked in projector
2.40 (also referred to as 2.35 and 2.39)	Widescreen (anamorphic) film projection

#### **Read more:**

http://www.widescreen.org/aspect\_ratios.shtml

http://filmmakeriq.com/lessons/the-changing-shape-of-cinema-the-history-of-aspect-ratio/

### Letterbox vs. Pan and Scan





### Pillarbox

#### Pillarboxing

Pillarboxing displays movies with a small aspect ratio on a wide screen. Black bars appear on the left and right sides of the frame.

1.33 pillarbox



1.78 frame

## Video compression

Compression – mathematical reduction of visual information in order to save computer disk space and maintain the essence of the picture.

- JPEG a standardized image compression mechanism. JPEG stands for Joint Photographic Experts Group, the original name of the committee that wrote the standard.
- MJPEG (Motion JPEG) a video compression scheme in which each frame is separately compressing using the JPEG standard
- MPEG A digital video standards developed by the Motion Pictures Expert Group

### MPEG standards

Read more about MPEG standards:
 Pank, Bob. The Digital Fact Book. 20th Aniverssary Ed. Converged Media. Pages 125 - 130.

#### Intra-frame compression



Intraframe compression works because each pixel of blue sky is almost exactly the same as the one next to it. The system needs to record only the differences.

Puhovski, Nenad. High Definition. Report from Cilect Standing Commitee for New Technologies. Madrid, 2006

## Intra-frame compression



Puhovski, Nenad. High Definition. Report from Cilect Standing Commitee for New Technologies. Madrid, 2006
## Inter-frame compression GOP - group of pictures

MPEG-2 12 frame GOP



## Inter-frame compression

I-frame (intraframe) – complete frame
 P-frame (predictive) – prognosis forward
 B-frame (bi-directional) – dual side prognosis

"P" and "B" frames include only data about the changes. They can not be individually edited or viewed. The video data is recreated by the image processor based on the GOP - Group of Pictures.

#### Intra-frame vs. inter-frame compression



Puhovski, Nenad. High Definition. Report from Cilect Standing Commitee for New Technologies. Madrid, 2006

### MPEG-2 vs. DV editing



Pank, Bob. The Digital Fact Book. 11th Ed, lk 49.

## Bit rate types

Constant bit rate (CBR) compression – compression is applied with constant bit rate.

Variable bit-rate (VBR) compression – depending on the image complexity the bit rate is changed.

VBR allows better quality wit the same file size than CBR.

 I-pass or 2-pass encoding – two times analysis gived better results but takes longer time

## Codecs optimized for editing

#### Apple ProRes

- https://www.apple.com/final-cut-pro/docs/Apple\_ProRes\_White\_Paper.pdf
- Avid DNxHR ja DNxHD
  - http://www.avid.com/US/industries/workflow/DNxHD-Codec
  - http://www.avid.com/static/resources/US/documents/DNxHD.pdf

## **Consumer SD video formats**







## Professional SD video formats



#### High Definition formats











DSLR camera formats (H.264/MPEG-4 AVC)



#### SD and HD video format comparison

- Standard definition PAL video
- 576i50 720x576 pixels, interlaced, 50 fields in second
  - 4:3 or 16:9 aspect ratio
- High definition video (in Europe)
  - 720p50 1280x720 pixels, progressive, 50 frames in second
    1080i50 1920x1080 pixels, interlaced, 50 field in second (or 25 frames in second)
    - HD video format has only 16:9 aspect ratio

# 4K 4096 x 2160

## **2K 2048 x 1080** Full HD 1920 x 1080





## Format comparison

480 DVD 720 720p 1280	1060	
1080p 1920		216

http://hometheaterreview.com/ultrahd-ultra-high-definition/

## **8K - UHDTV** 7680x4320



## **2K - HD** 1920x1080

http://www.ultrahdtv.net/what-is-ultra-hdtv/ http://www.youtube.com/watch?v=9U7e\_quvkPQ https://www.youtube.com/watch?v=XoN96BM07bE

#### HDTV vs DCI digital cinema formats

I6:9 HDTV 1920 x 1080 (1.78:1)
 I6:9 UHDTV 3840 x 2160 (1.78:1)

- 2K Full Container 2048 x 1080
- 2K Flat 1998 × 1080 (1.85:1)
- **2K Scope** 2048 x 858 (2.39:1)
- 4K Full Container 4096 x 2160
- **4K Flat** 3996 × 2160 (1.85:1)
- **4K Scope** 4096 x 1716 (2.39:1)

## DCI - Digital Cinema Initiatives

- Picture: JPEG2000 coding
- CIE XYZ color space
- I2 bit for each color channel (36 bits per pixel)
- Max bit rate 250 Mbit/sec
- Sound: 24 bit, sampling rate 48 kHz or 96 kHz,
- WAV uncompressed PCM
- <u>http://www.dcimovies.com</u>
- http://www.jamesmilnersmyth.com/prepare-project-dcp-digital-cinema-package/

#### International standards

- ITU-R BT.601 Studio Encoding Parameters of Digital Television for Standard 4:3 and Wide-Screen 16:9 Aspect Ratios
- ITU-R BT.709 Parameter Values for the HDTV Standards for Production and International Programme Exchange
- ITU-R BT.2020 Parameter Values for ultra-high definition television systems for production and international programme exchange
- ITU International Telecommunications Union is a specialized agency of the United Nations (UN) that is responsible for issues that concern information and communication technologies.

Read more: <u>http://www.itu.int/rec/R-REC-bt</u>



### Memory cards



CF (CompactFlash)







SD (Secure Digital) SDHC (High Capacity) SDXC (Xtra Capacity)



CFast 2.0





Sony Memory Stick Pro Duo

Sony SxS Pro

http://en.wikipedia.org/wiki/Comparison\_of\_memory\_cards

## Panasonic P2 and Micro-P2 format



P2 – "Professional Plugin"







#### Selection of digital film cameras used in the film industry

Arri Alexa ja Amira

http://www.arri.com/camera/alexa

- http://www.arri.com/camera/amira
- Red Weapon, Epic, Scarlet, Raven

http://www.red.com

Sony CineAlta cameras (F65, PMW-F55, PMW-F5, PMW-F3, FS7 II)

http://pro.sony.com/bbsc/ssr/show-highend/

Canon Cinema EOS cameras (C700, C500, C300 mkll, C100 mkll)

http://cinemaeos.usa.canon.com

Blackmagic Design (Ursa, Ursa Mini Pro, Ursa Mini, Micro Cinema Camera, Cinema Camera, Pocket Cinema Camera)

https://www.blackmagicdesign.com/products

• Comparison charts (cameras, lenses):

http://nofilmschool.com/2016/12/camera-comparison-chart-2016-fletcher-adcock

#### Camera systems used in BFM

<u>https://www.tlu.ee/en/bfm/about-usbfm-production-centre/user-manuals</u>



#### Watch yourself

THE HISTORY OF CUTTING – THE BIRTH OF CINEMA AND CONTINUITY EDITING <u>https://www.youtube.com/watch?v=6uahjH2cspk</u>

THE EVOLUTION OF MODERN NON-LINEAR EDITING: PART 1 – FROM TAPE TO DIGITAL <a href="https://www.youtube.com/watch?v=TIVYeyWHajE">https://www.youtube.com/watch?v=TIVYeyWHajE</a>

THE EVOLUTION OF MODERN NON-LINEAR EDITING: PART 2 – THE DIGITAL REVOLUTION https://www.youtube.com/watch?v=dhHQw5GrwxU

## Suggested readings

- Ascher, Steven & Pincus Edward. The Filmmaker's Handbook. A Comprehensive Guide for the Digital Age. 4th ed. Plume 2013.
- Ward, Peter. Digital Video Camerawork. Media Manual. Focal Press 2000
- Browne, Steven E.Video Editing. A Post-Production Primer. Focal Press, 1997.
- Pank, Bob. The Digital Fact Book. <a href="http://www.quantel.com/resource.nsf/Files/">http://www.quantel.com/resource.nsf/Files/</a>
- Quantel\_Digital\_Factbook/\$FILE/Quantel\_Digital\_Factbook.pdf>
- Pank, Bob. Digital Film Supplement. <a href="http://www.quantel.com//resource.nsf/Files/Digital\_Film/\$FILE/Digital\_Film.pdf">http://www.quantel.com//resource.nsf/Files/Digital\_Film/\$FILE/Digital\_Film.pdf</a>.
- Ward, Peter. Digital Video Camerawork. Media Manual. Focal Press, 2000.
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- John Watkinson "The Art of Digital Video" Focal Press, 2000