Design of Multimedia Applications: Video Shot Detection, Annotation, & Retrieval

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Lectures and Exercises

- Two introductory lectures
  - topics
    - error correction in digital video (27 September)
    - video shot detection, annotation, & retrieval (25 October)
  - complementary to the theory lectures
  - background information

- Exercises
  - under supervision in PC Class A and PC Class B
  - every Monday, from 16h00 till 18h45
    - attendance not mandatory

Outline

- Introduction
- Techniques for video shot detection
  - pixel-wise comparison
  - selective pixel comparison
  - block-based comparison
  - motion estimation
  - histogram-based comparison
- Performance evaluation

algorithmic development

- DirectShow

application development

- Assignment

Introduction (1/4)

- Increasing **consumption** of online video content
  - thanks to easy-to-use (mobile) devices & online services
  - thanks to cheap storage and bandwidth
  - thanks to an increasing number of people going online
- Increasing **availability** of online video content
  - thanks to the digitization of professional video archives
  - thanks to the popularity of user-generated video content

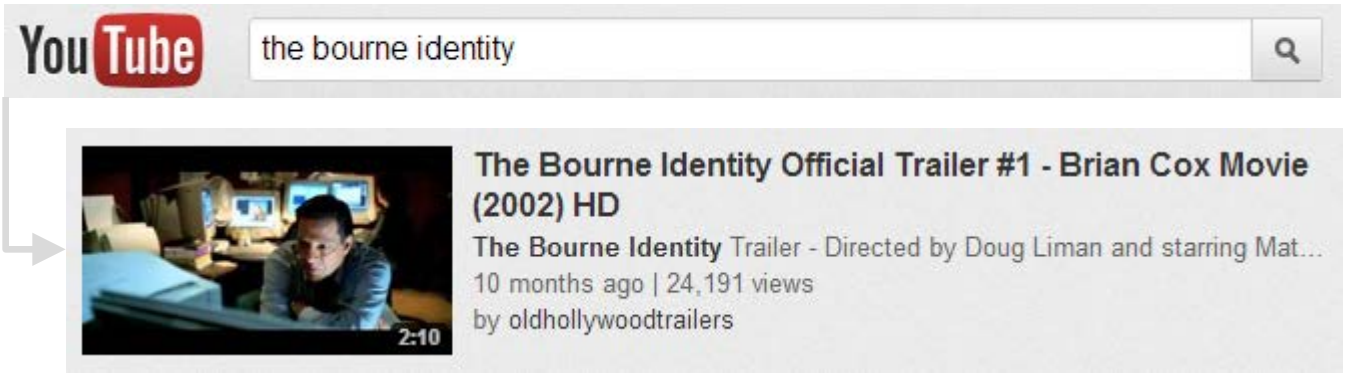
Introduction (2/4)

- Some statistics
  - professional video content
    - BBC Motion Gallery (as of January 2009)
      - contains over 2.5 million hours of video content
      - with some video content dating back 60 years in time
  - user-generated video content
    - YouTube (as of October 2013)
      - people watch over 6 billion hours of video each month
      - people upload 100 hours of video each minute

Introduction (3/4)

- Problem: digital video overload (infobesity)
  - our ability to organize video clips does not keep up with our ability to create video clips

- Bottleneck: manual annotation
  - to organize video clips, we need to add descriptions to video clips ourselves (cf. text-based retrieval of video)



Introduction (4/4)

- Solution: automatic video content understanding
  - identification of the temporal structure of video clips
    - scenes and shots
  - use of machine learning (e.g., SVM, deep learning) to translate binary pixel values into text labels (tags)
    - e.g., ‘people’, ‘building’, ‘news’, and so on

Shot 1: ‘surveillance camera’

Shot 2: ‘Jason Bourne’, ‘people’

Goal Lab Session

- To give a better insight into the problem of organizing large collections of **video clips** by
  - implementing and evaluating a number of state-of-the-art algorithms for automatic **video shot detection**
  - and by subsequently integrating these algorithms into a **DirectShow-based application** that offers support for the **manual annotation and tag-based retrieval of video shots**

Video Shots (1/2)

- Video shot
  - set of consecutive pictures
    - taken by a single camera
    - represent a continuous action in time and space

- Video shot detection
  - automatic detection of the start (and end) of shots
  - also referred to as
    - shot boundary detection
    - shot transition detection

Video Shots (2/2)

- Video shots
  - cuts: instantaneous transition between two shots

  - dissolves: gradual transition between two shots

  - fades: gradual transition between a shot and an image

⇨ to detect shots, compute and interpret frame differences

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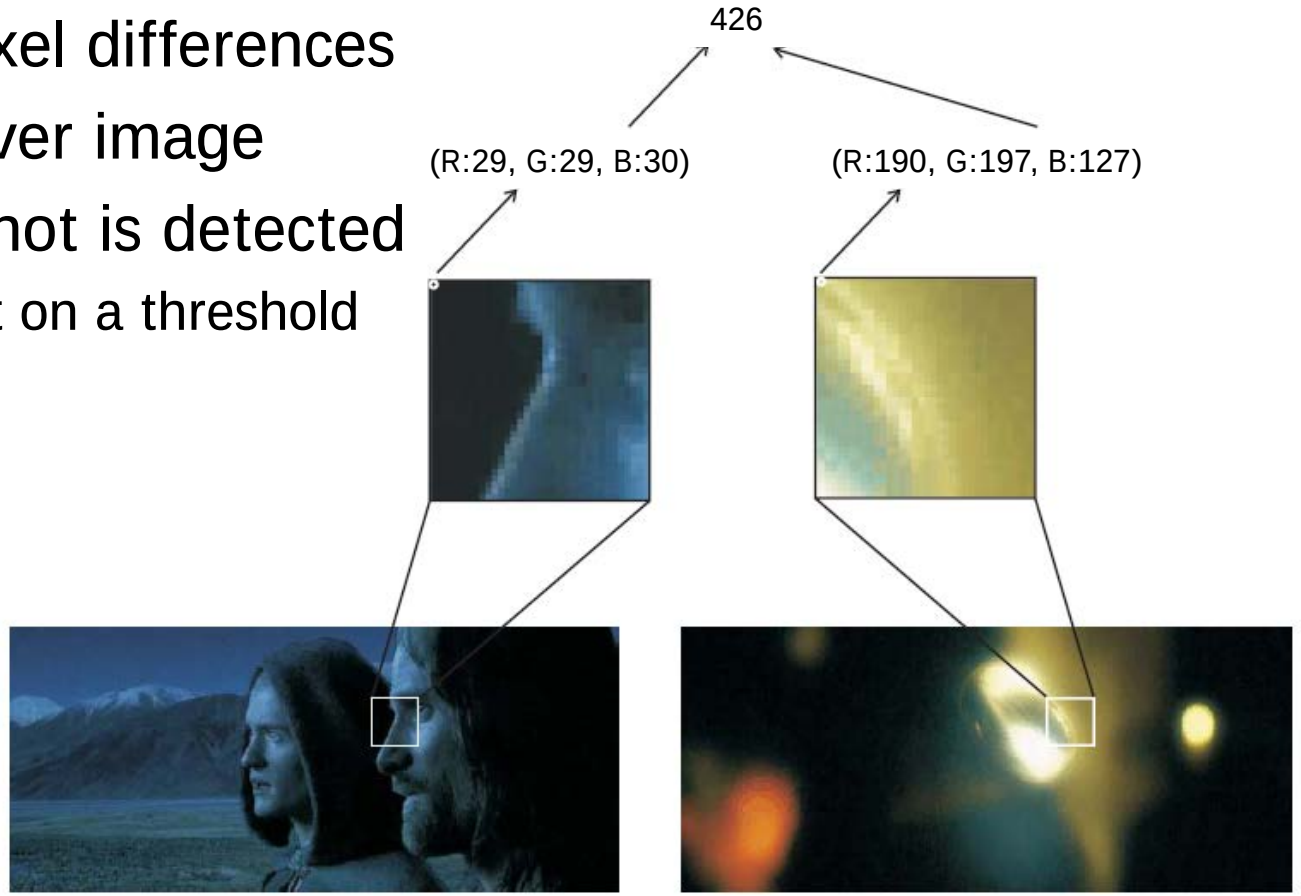
Pixel-Wise Comparison

- Approach
  - calculate pixel differences
  - averaged over image
  - if large, a shot is detected
    - dependent on a threshold



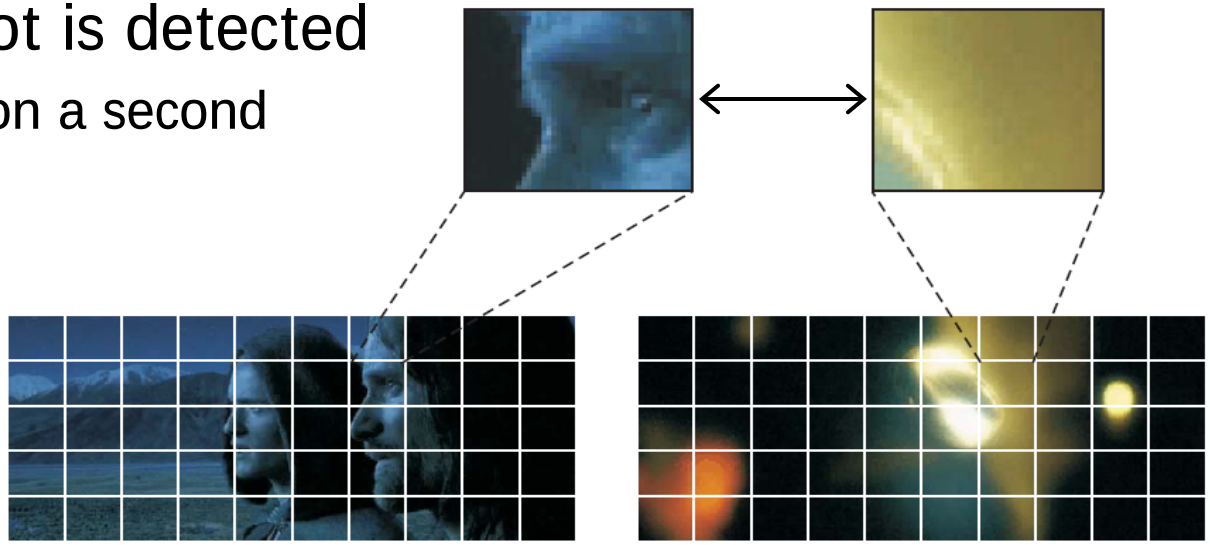
Selective Pixel Difference

- Approach
  - only use large pixel differences
    - dependent on a first threshold
  - **count** the number of large pixel differences
    - average over the image
    - if large, a shot is detected
      - dependent on a second threshold

- Prevents that lots of small differences have an influence on the detection of shots
  - small camera or object movement may have a substantial influence on the pixel differences

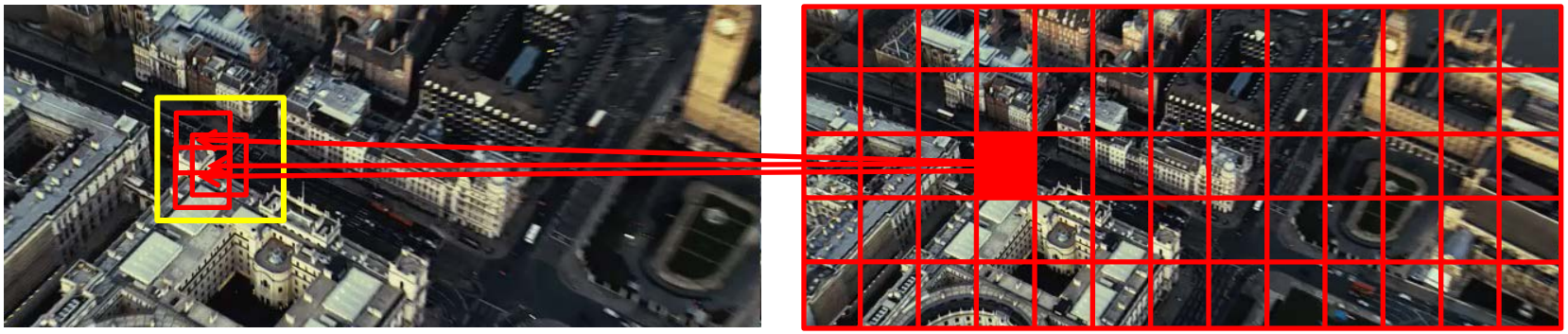
Block-based Comparison

- Approach
  - calculate block differences
  - count the number of **blocks** that have a large difference
    - dependent on a first threshold
  - if large, a shot is detected
    - dependent on a second threshold



Motion Estimation (1/3)

- Approach
  - divide current image into blocks
  - search for best matching block in previous image
    - search window centered around block position
    - calculate block difference
    - best match minimizes the block difference



Motion Estimation (2/3)

- Approach
  - sum the matched block differences to find the overall image difference
  - if large, a shot is detected
    - dependent on a threshold

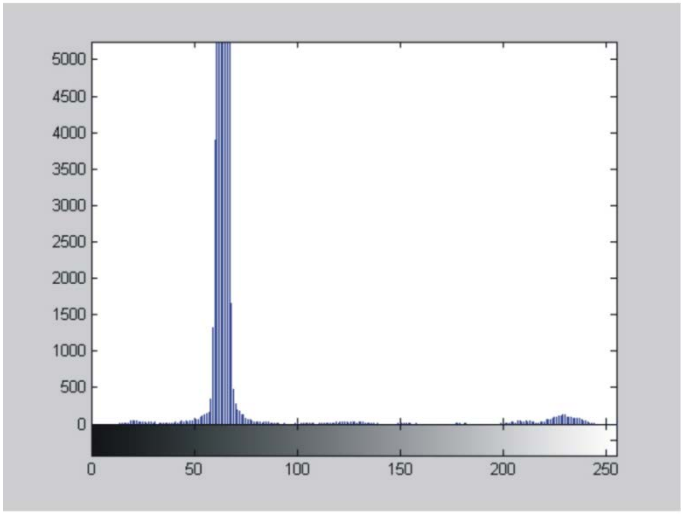
- Problem: exhaustive search is slow for large windows
  - coarse-to-fine search
    - first look at a subset of blocks in the search window
    - find the best match
    - look at blocks close to this best match
    - find a better match

Motion Estimation (3/3)

- Coarse-to-fine motion estimation

Histogram-based Comparison (1/4)

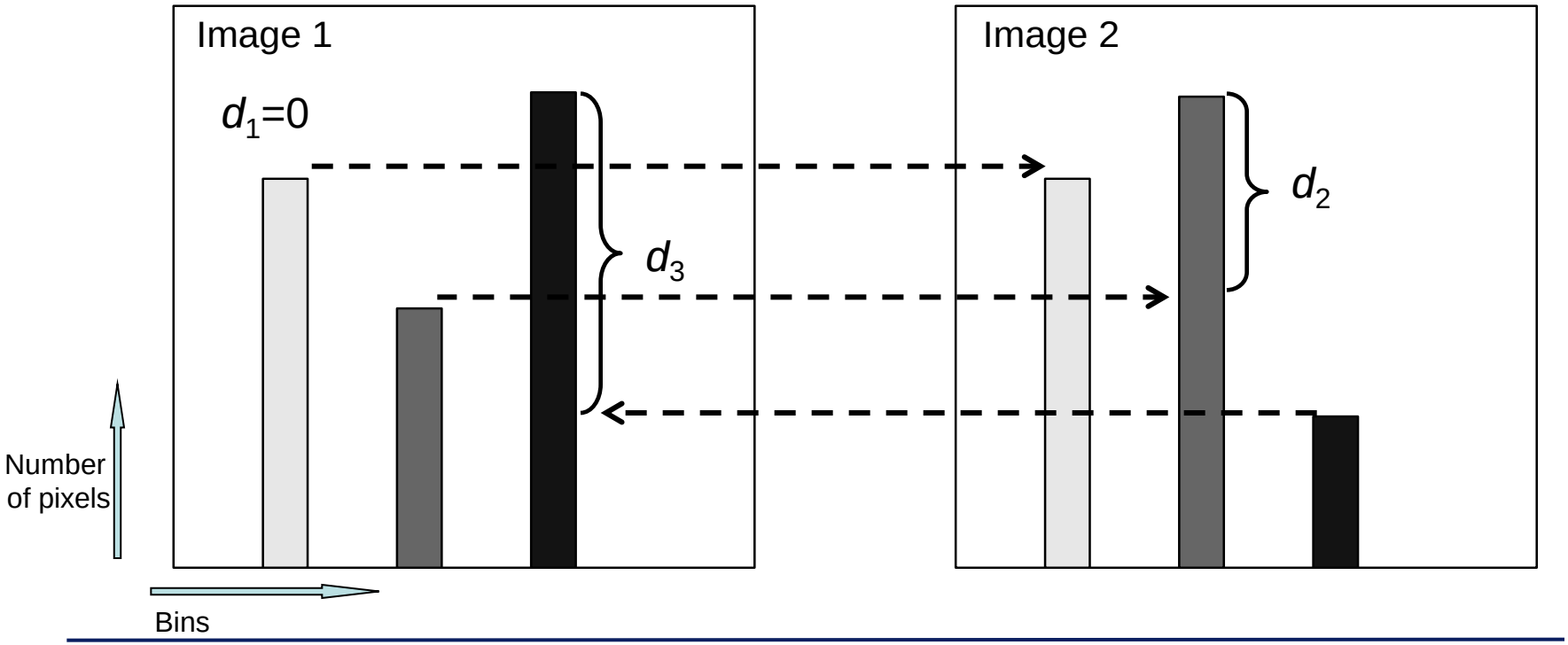
- Approach
  - count the number of pixels that have a certain color
  - image difference = histogram difference



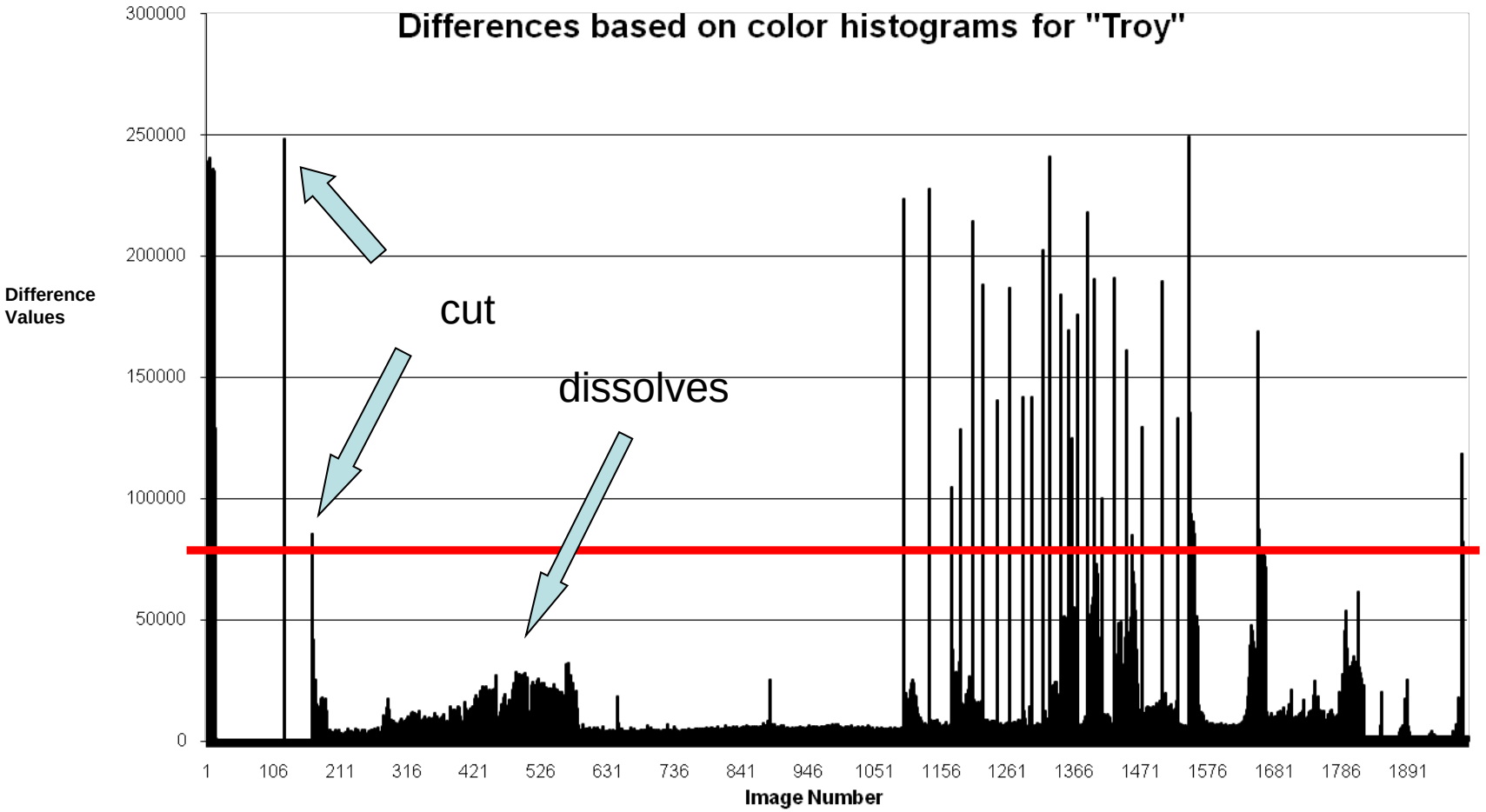
  - use of bins allows reducing the complexity
    - groups pixels that have a color within a certain range

Histogram-based Comparison (2/4)

- Histogram difference
  - for each bin, compute the difference
  - many distance metrics possible: L_1, L_2, EMD, SQFD, ...

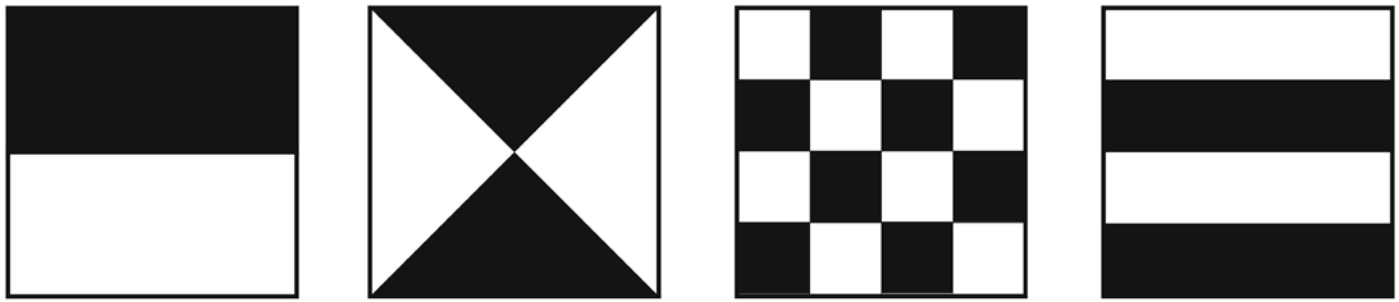


Histogram-based Comparison (3/4)



Histogram-based Comparison (4/4)

- Global histogram comparison
  - problem: different images can have similar histograms



  - solution: local histogram comparison
    - calculate histograms for regions in the image
      - takes into account discriminative spatial information
    - sum histogram differences of corresponding regions in consecutive frames
    - often used in practice (and in other application domains)

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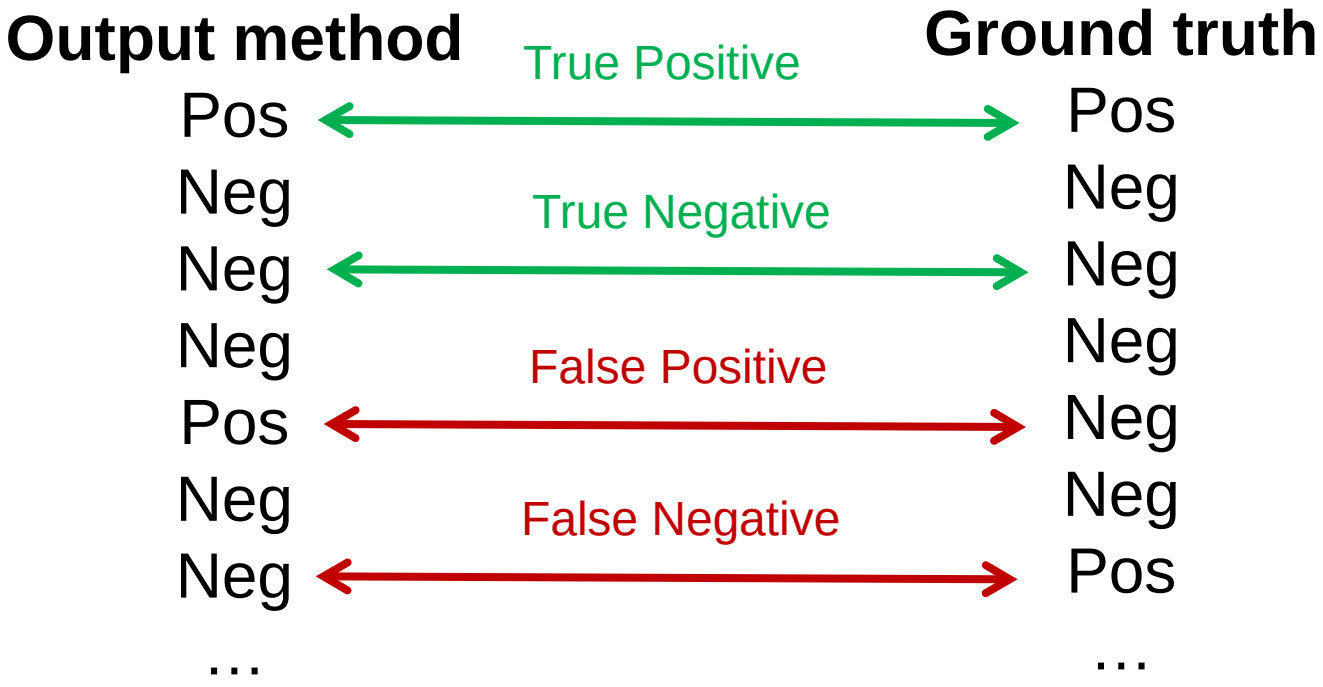
Evaluation (1/4)

- Outcome of a particular shot detection technique
  - shot detected: referred to as a “positive”
  - no shot detected: referred to as a “negative”
    - “positives” and “negatives” can either be true or false

- Verification by means of a ground truth
  - allows comparing the output of a shot detection technique with what is in the video clip in reality
  - manually created and trustworthy
    - use of human computing (e.g., Amazon Mechanical Turk)
  - used in many other application domains
    - e.g., face recognition, video copy detection, ...

Evaluation (2/4)



- Goal
  - maximize *true* positives and *true* negatives
  - minimize *false* positives and *false* negatives

Evaluation (3/4)

- Precision and recall
  - precision: percentage of correctly detected shots
  - recall: percentage of all real shots detected
    - sometimes also combined into an F_1-score (harmonic mean)

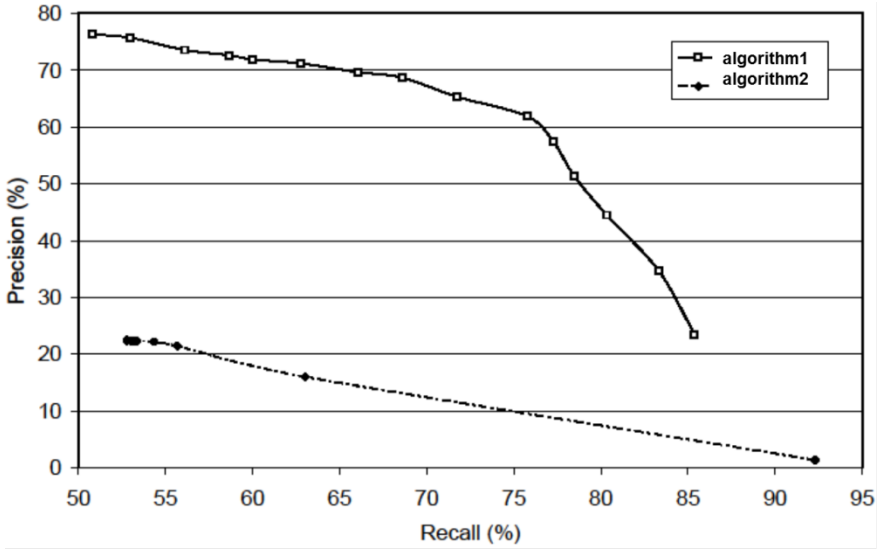
$$precision = \frac{TruePositives}{TruePositives + FalsePositives}$$

$$recall = \frac{TruePositives}{TruePositives + FalseNegatives}$$

  - the higher the precision and the recall, the better

Evaluation (4/4)

- Apply different shot detection techniques, and make use of varying parameter values
  - count correct and wrong detections
  - calculate precision and recall values
  - plot summarizing ROC (Receiver-Operator-Curve)



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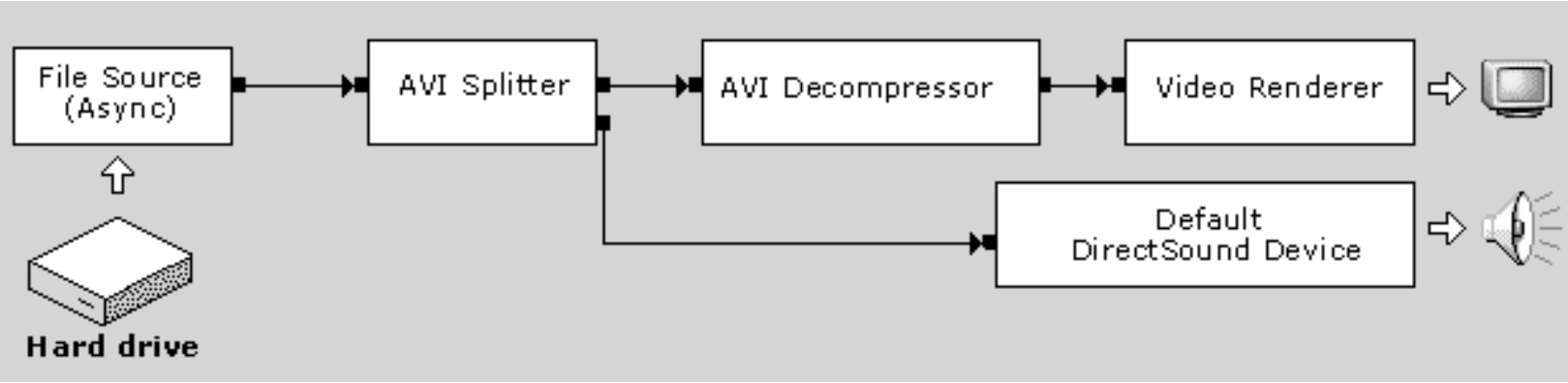
DirectShow (1/3)

- DirectShow
  - framework for processing of multimedia streams
  - successor of the Video for Windows API
    - alternative to the QuickTime API (Apple)

- Designed for C++ & the Component Object Model (COM)
  - complicated but still widely used by the industry
  - in our exercises, a C# wrapper will be used
    - DirectShow.Net Library

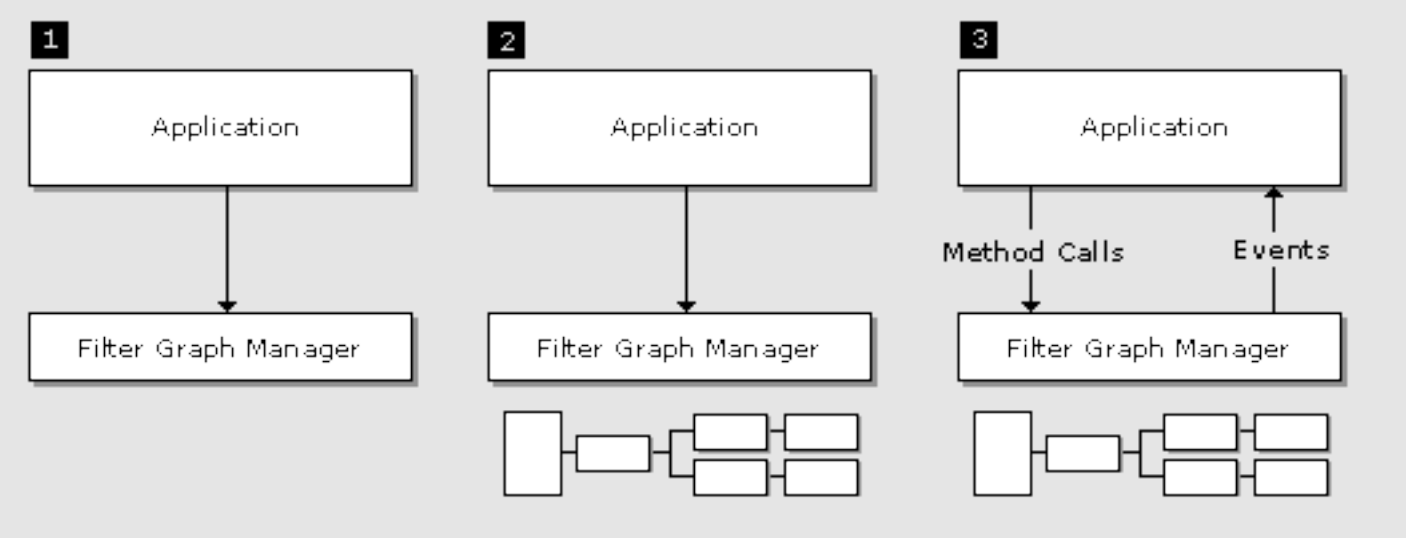
DirectShow (2/3)

- Filters are the building blocks of DirectShow
  - source filter
  - transform filter
  - renderer filter
- Filters are connected into a Filter Graph
  - can be visualized by means of the GraphEdit tool



DirectShow (3/3)

- DirectShow application
  - (1) gets an instance of the Filter Graph Manager
  - (2) builds a filter graph
  - (3) steers the filter graph and responds to events



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Assignment (1/4)

- Create a DirectShow-based C# application
  - needs to come with a GUI
  - required functionality
    - open video
    - play video (see example applications)
    - detect shots (see algorithms)
    - show shots
    - play shot
    - annotate shot
    - export shot info
    - export frames
    - retrieve shots

Assignment (2/4)

- Algorithms
  - Exercise 1
    - implementation of selective pixel difference
  - Exercise 2
    - implementation of motion estimation method
  - Exercise 3
    - implementation of global histogram comparison
  - Exercise 4
    - implementation of local histogram comparison

cuts

  - Exercise 5
    - implementation of generalized method for shot detection

cuts & gradual transitions

Assignment (3/4)

- Exercise 6: evaluation and report
  - precision and recall, as well as time complexity
  - write a report
    - clear information about the algorithms implemented
    - evaluation of the algorithms implemented
    - answer the questions given
  - important!
    - report has to be clear and well-structured
      - choose the best way to visualize your results
    - size of the report
      - absolute maximum: 6 pages
      - quality above quantity!

Assignment (4/4)

- Deadlines
  - software (application + algorithms)
    - December 5th, 16h00 (Thursday)
  - report (in English)
    - December 12th, 16h00 (Thursday)