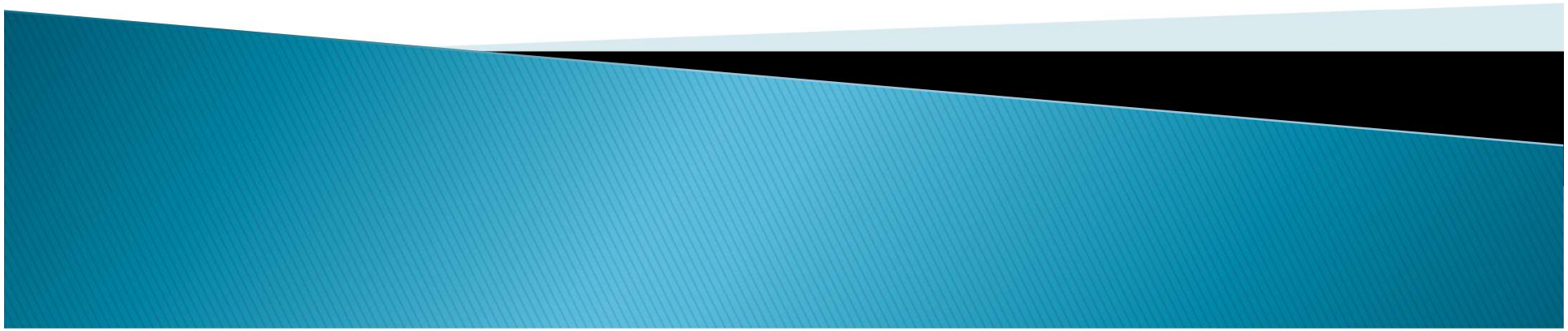
Multimedia Databases
Introduction

Prof. Dr. Mario Döller & Prof. Dr. Harald Kosch & Prof. Dr. Michael Granitzer
Chair of Distributed Information Systems / Chair of Data Science



General Information I

- Organisation
  - Stud.IP
  - Office hours (Sprechstunde): Mo, 16-18, Upon request per Email to Stefanie.Riederer@uni-Passau.de
  - All Material available on Stud.IP

- Credits
  - Master Computer Science in the Focus Group “Information and Communication Systems”
  - Master Computational Mathematics in the Focus Group “Data Analysis and Data Management and Programming”
  - Master AI Engineering in the Module Group “AI Applications“
  - Double-Master Informatique-Informatik Lyon-Passau

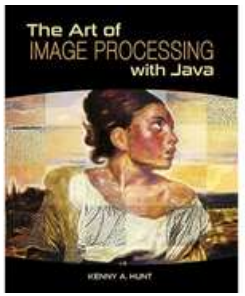
- Exams
  - Written exam, 90min

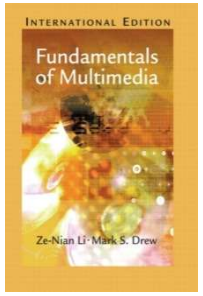
General Information II

- Lecturers:
  - Prof. Mario Döller
  - Prof. Harald Kosch
- The first three lectures take place 16-18 each Tuesday (28.4, 25.4, 2.5) in HS 13.
- Further lectures, times and locations see Stud.IP
- Lecture slides and support material is available before.
- Exercises are done by Kanishka Ghosh Dastidar Kanishka.GhoshDastidar@uni-passau.de and Alaa Alhamzeh alaa.alhamzeh@uni-passau.de
- Information on the schedule is given in Stud.IP by Kanishka Ghosh Dastidar and Alaa Alhamzeh

Literature of the course

- Books
  - Meinel & Sack, Digital Communication, Springer, 2014
  - Steinmetz R & Nahrstedt K, “Multimedia Technologie: Grundlagen, Komponenten und Systeme”, 3. Auflage , Springer, 2000.
  - **Steinmetz R & Nahrstedt K, “Multimedia Systems”, Springer-Verlag, Berlin, Heidelberg, New York, 2004**
  - **Steinmetz R & Nahrstedt K, “Multimedia Applications”, Springer-Verlag, Berlin, Heidelberg, New York, 2004**
  - Ze-Nian Li & Mark S. Drew, "Fundamentals of Multimedia", Pearson Education, 2004.
  - Harald Kosch: “Distributed Multimedia Database Technologies supported by MPEG-7 and MPEG-21”, CRC Press, November 2003, ISBN 0-8493-1854-8.
  - Kenny A. Hunt: "The Art of Image Processing with Java", CRC Press, 2010.
- Conferences
  - ACM Multimedia
  - IEEE International Conference on Multimedia & Expo (ICME)
  - …
- Journals
  - IEEE MultiMedia
  - Multimedia Tools and Applications
  - …





Topics of the lecture

Topics	Contents
01 Introduction	Definition, Multimedia according to Steinmetz, Media Types, Development of MM-DB
02 Colors	Color and Color Perception
03 Image medium	Raster graphics/Vector graphics, Image formats, Image manipulation (Filter, etc.)
04 Video/Text/Audio	Basics of media (formats, etc.), technology for video segmentation etc.
05 Compression	Encoding and compression of media data
06 Modeling	Modeling of media data (MPEG-7)
07 CBIR	Information- and content based retrieval of media data
08 Query languages	Characteristics and types of MM query languages and MM query processing

Topics of the lecture

Block	Contents
09 Index Structures	High dimensional feature vectors indexing techniques
10 Systems	Presentation of current systems (commercial/research) for media storage and retrieval

Literature of the „Introduction“

- **Main literature:**
  - Steinmetz R & Nahrstedt K, “Multimedia Systems”, Springer-Verlag, Berlin, Heidelberg, New York, 2004
  - Steinmetz R & Nahrstedt K, “Multimedia Applications”, Springer-Verlag, Berlin, Heidelberg, New York, 2004
- **Supplemental Article:**
  - Zixia Huang, Klara Nahrstedt, and Ralf Steinmetz. 2013. Evolution of temporal multimedia synchronization principles: A historical viewpoint. ACM Trans. Multimedia Comput. Commun. Appl. 9, 1s, Article 34 (October 2013),
  - https://dl.acm.org/doi/10.1145/2490821

Table of Contents
Introduction

Parts of the lecture adapted from the set of slides provided by Prof. Dr. Andreas Henrich, University of Bamberg

Table of Contents
Introduction

Parts of the lecture adapted from the set of slides provided by Prof. Dr. Andreas Henrich, University of Bamberg

Multimedia Definition I

- *Multi* – many, various, …
- *Medium* – *a substance regarded as the means of transmission of a force or effect; a channel or system of communication, information, or entertainment*

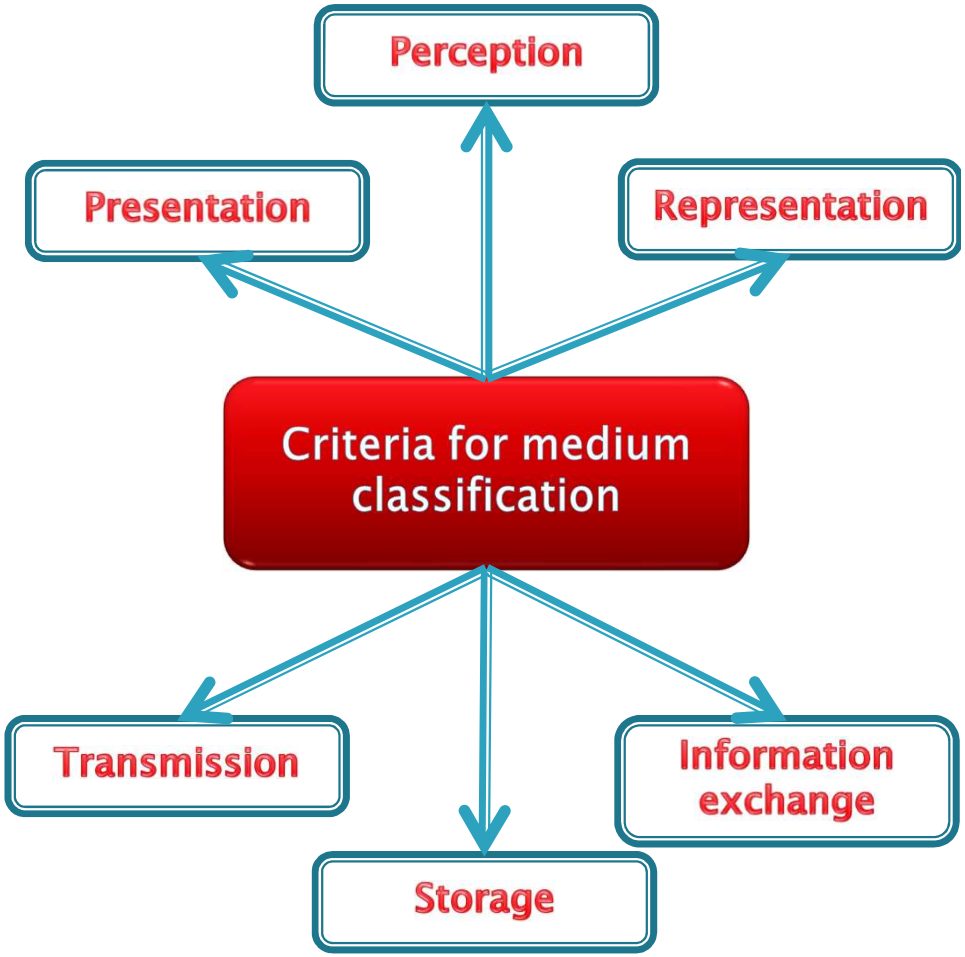
(Merriam-Webster Dictionary)

– *An intervening substance through which something else is transmitted or carried on* (FreeDictionary)

- So, **Multimedia**???
  - The term Multi & Medium does not make a lot of sense!
  - The notion of "medium" must be further investigated

Multimedia Definition II

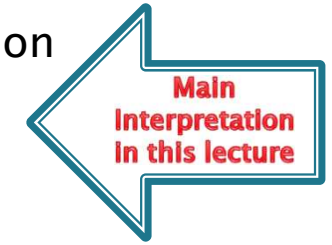
- Medium as defined by the Multimedia and Hypermedia Experts Group (MHEG) of ISO
  - Medium
    - Means of distributing and presenting information
  - Classification based on perception, presentation, representation, transmission etc.



➡ Is adequate to the definition of multimedia

Multimedia Definition III

- The medium of perception (Perception = Sensory perception)
  - Primary differentiation by Hearing and Eyesight (+haptic)
- The medium of representation
  - Reference to the internal computer presentation of the information
  - Formats for text, graphics, single image, animated pictures, …
- The medium of presentation
  - Reference to in- and output
  - Output media: Paper, screen, loudspeakers, …
  - Input media: Keyboard, camera, mouse, microphone, …
- The medium of storage
  - Distinction based on the data carrier: magnetic discs, DVD, paper, …
- The medium of transmission
  - By what means is the information transferred? Coaxial cable, glass fiber, …
- The medium of information exchange
  - What information carriers are used for the exchange between various spots? (storage media + transfer media)



Multimedia Definition IV

- Space and Time dimensions for representing media
- Time is an important dimension in the representation of the media.
- Wrt. time, a medium may be qualified as:
  - Time independent (*discrete*)
    - Ex.: Text, Graphics
  - Time dependent *(continuous*)
    - Continuous sequences of time-dependent values
    - Ex.: Audio, Video

- The characteristics discrete/continuous do not constrain the internal representation of the medium – they only refer to the impression of the user at presentation time)

Multimedia Definition V

- In the most general sense, Multimedia is *any* combination of *digitally manipulable types of media* (text, sound, image, animation, video).

- A *stricter* version of this definition subsequently restricts the possible combinations of media:
  - It requires:
    - Mixing of both continuous and discrete media
    - A significant degree of independence between these media

- The less strict definition is very common in practice.
- Independence between mixed media is a usual feature of multimedia databases

Multimedia Definition VI

- Multimedia elements can be produced by means of *authoring systems* (Flash/SMIL/HTML 5 etc.).
- *Multimedia authoring systems* are programs that provide means to create complete multimedia presentations by interlinking objects (text, audio, illustrations, etc.) and taking interactive, user-related processes into account
- Adobe Director, Dreamweaver, MS Powerpoint,…

Multimedia Definition VII

- Multimedia is *interactive* when the user is able to control which elements are delivered and when
- Interactive multimedia is *hypermedia* when the users are presented with a structure of linked elements in which they can navigate.
  - Example: Simple Interactive Video Authoring Suite (SIVA) producer, the interactive video authoring tool of the Mirkul project

    http://www.mirkul.uni-passau.de/

Multimedia Definition VIII

- Multimedia is *linear* when it can only be presented in a single continuous flow over time.
  - Examples:
    - Film
    - Internet Radio
  - (in general, linear multimedia is non-interactive)

- Multimedia is *non-linear* when it consists of a set of elements that may be presented according to different flows
  - Examples:
    - Games
    - Interactive CD
    - SIVA interactive video

Table of Contents
Introduction

Parts of the lecture adapted from the set of slides provided by Prof. Dr. Andreas Henrich, University of Bamberg

Multimedia System

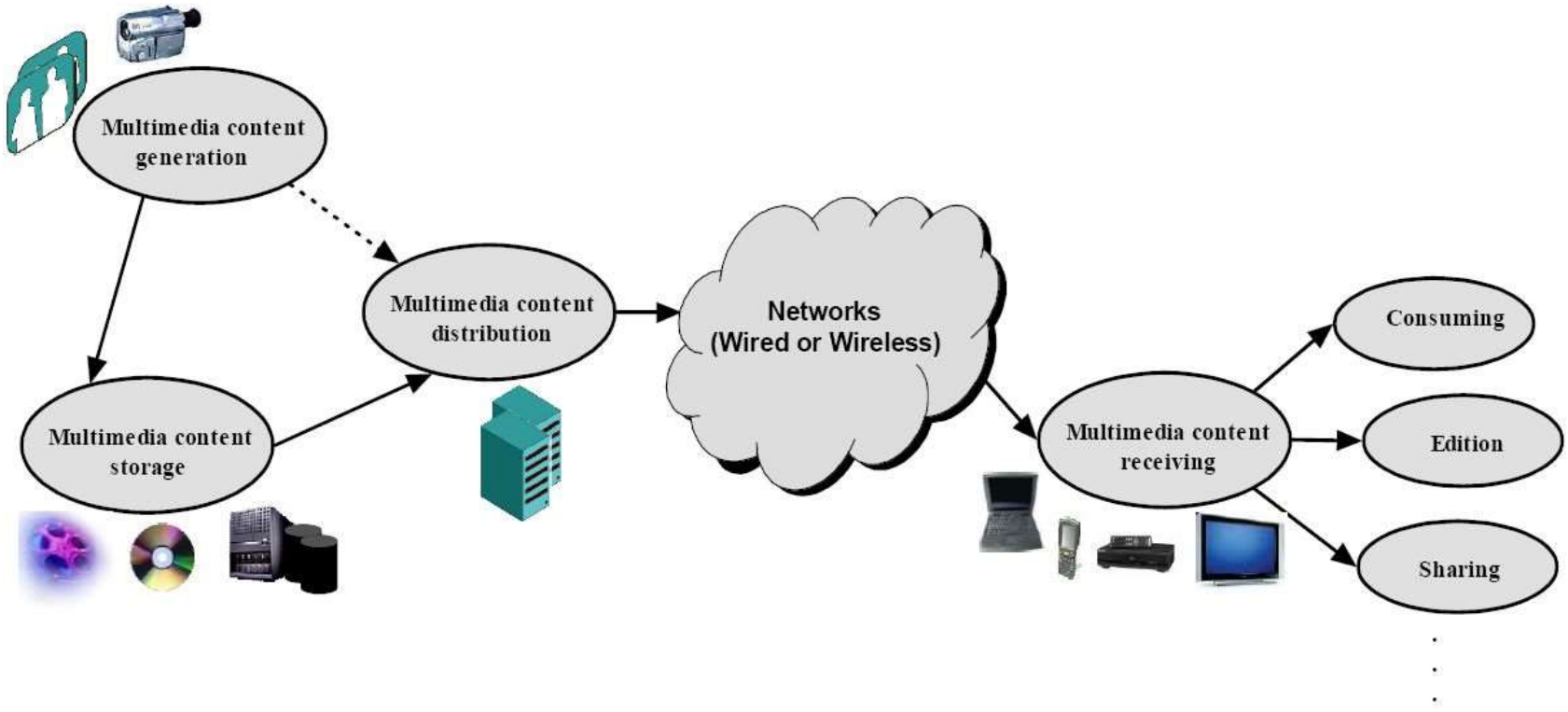
- Definition:
  - *A Multimedia System is characterized by the computer-controlled generation, manipulation, presentation, storage, and communication of a set of independent media, which include at least one continuous (time-dependent) and one discrete (independent of time) medium.*[1]

[1] Adapted from R. G. Herrtwich, R. Steinmetz, Towards Integrated Multimedia Systems: Why and How, Telekommunikation und multimediale Anwendungen der Informatik, Informatik-Fachberichte Vol 293, 1991, pp. 327-342

Essential Characteristics of A Multimedia System

- Combination of media
  - An MM application should be able to *process* at least one discrete and one continuous medium!
- Independence
  - No rigid connection between the combined media
- Computer-aided integration: integrated MM-Systems
  - Not only recording and presentation but also other functions
  - Example: temporal, spatial, content-related synchronization
- Communicating systems
  - Realization of MM-systems in distributed environments

Multimedia System-Architecture

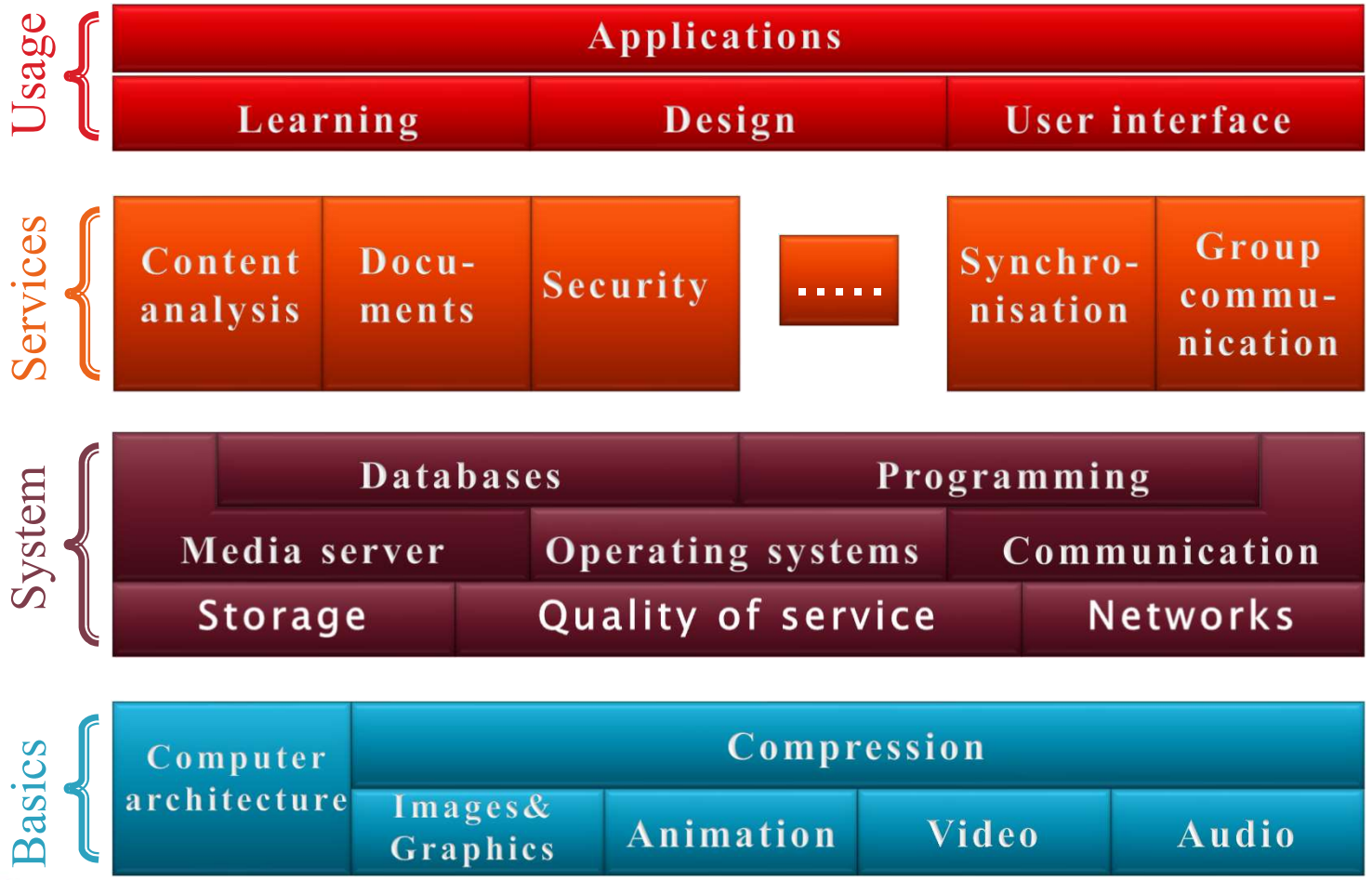


(c) Shiguo Lian, Dimitris Kanellopoulos, Giancarlo Ruffo; **Recent Advances in Multimedia Information System Security**; *Informtica*; 33(1):3-24; 2009

Table of Contents
Introduction

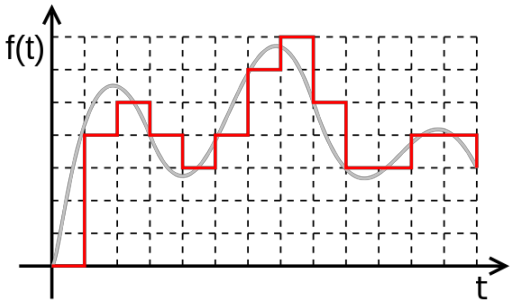
Parts of the lecture have been adopted and applied from the set of slides provided by Prof. Dr. Andreas Henrich, University of Bamberg

Multimedia – Main Domains



(According to Ralf Steinmetz: *Multimedia-Technologie*, 2. edition, Springer, 1999)

- Basic principles for the processing of digital audio/video data:
  - Nyquist–Shannon sampling theorem and Pulse Code Modulation
  - Different techniques, specialized in the respective medium
  - Audio technology include music and speech processing
  - Video technology based on (digital) television technology
- Further considered:
  - Single images, graphics, animations, text
- With current quality requirements:
  - efficient, quality–preserving compression necessary (mp3, jpeg etc.)
- Aim:
  - Fully digital systems



PCM

f(t)	0	4	5	4	3	4	6	7	...
t	1	2	3	4	5	6	7	8	...

Digital Signal

- Central aspect: Quality of service
  - Represents a defined, controllable system behavior according to measurable parameters
- Basic Functionalities:
  - Processing
    - Task of operating systems and programming environment:
      - abstracted interface to the computer hardware
    - Abstraction can be provided by the MM-operational system, a computer language or a OO-class hierarchy
  - Storage
    - Usage of specific storage devices; the stored multimedia is managed by e.g. a media server or a DBMS
  - Communication
    - Multimedia imposes a number of requirements on communication networks:
      - high bandwidth
      - high level of reliability in order to meet the time constraints (video streaming)

Services provide ready-to-use integrated functions to user applications

- Communication
  - e.g. Email, conferencing applications, joint editing
  - These services need to take into account the constraints of multimedia
- Synchronization
  - Establish a temporal relation between multimedia data items (e.g. Games)
- Security
  - Measures to prevent attacks
- Documents
  - Structuring of different media to form a "whole" (= a MM document)
- Content analysis
  - Considers the semantics of the contents
  - Enables more effective access and new types of applications

Applications and user interfaces represent the user-perceivable aspects of multimedia data

- Important: the question of MM-specific design
- Examples of applications:
  - E-teaching and e-learning
- Areas of increasing importance:
  - Specific tools for MM applications development
  - Project management for MM applications development
- But:
  - There is more to MM-Systems than just MM-applications development!

Table of Contents
Introduction

Data streams I

- A *data stream* is a sequence of individual packets that are transmitted under time-dependent constraints
  - Packets can include any information (continuous or discrete)

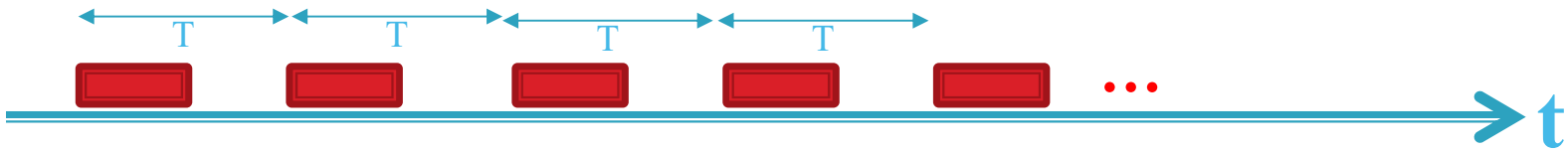
- Modes of transmission
  - Asynchronous
    - Packets should reach the recipient as soon as possible – but no guarantee is provided
    - Perfectly suitable for discrete media
    - For continuous media, additional temporal restrictions may have to be considered (when streaming)

Data streams II

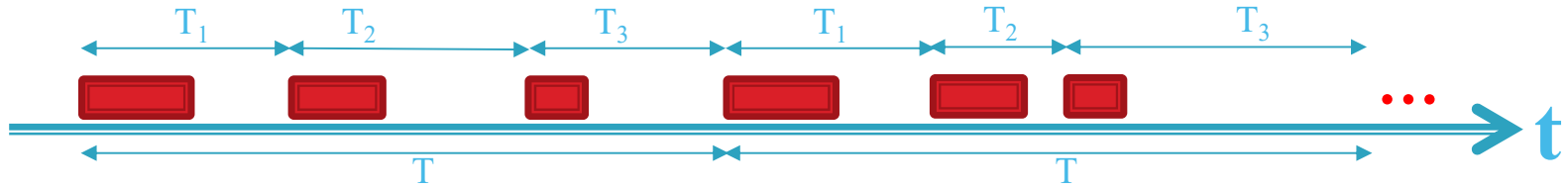
- Synchronous
  - Defines a maximal end-to-end delay
  - Packets may also arrive earlier
  - Sufficient memory is required on the receiver side! Ex: processing uncompressed video data with a data rate of 150 Mbps and a maximal end-to-end delay of 1 second to the recipient, 18.75 Mbytes of memory are required.
- Isochronous
  - Defines a maximal & minimal end-to-end delay
  - Reduces storage requirements on the receiver

Characterisation of continuous data streams I

- Periodicity of the transmission
  - Strongly periodical
    - Ex: PCM –Pulse-Code Modulation to encode speech for VoIP



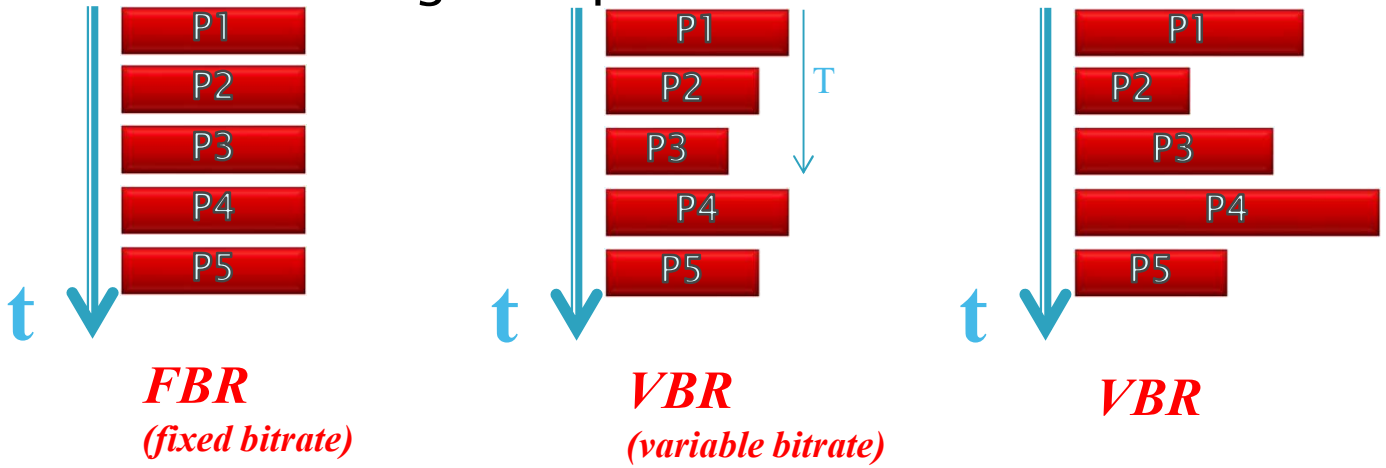
  - Weakly periodical: periodic properties every n packets



  - Aperiodic
    - Ex: Cooperative applications with a shared window

Characterisation of continuous data streams II

- Variations of contiguous packet sizes



  - Strictly even (Strictly regular)
    - Uncompressed digital data transmission
  - Weakly even/regular
    - MPEG Standard → fixed recurring pattern of 3 types of frames I, B, P with fixed size ratio
  - Uneven/Irregular

Table of contents
Introduction

Discrete Media

- discrete = static = independent of time
- The information is displayed in a time independent way, the duration of use is determined by the receiver
- Examples
  - Text (font)
  - Graphics (drawings, diagrams, etc.)
  - Real pictures (Photography, etc.)

Continuous media

- Audio
  - Speech
  - Music
  - Tones, sounds, noises
- Video
  - Real film
  - Animation

Predetermined temporal sequence

Summary of this unit
Introduction

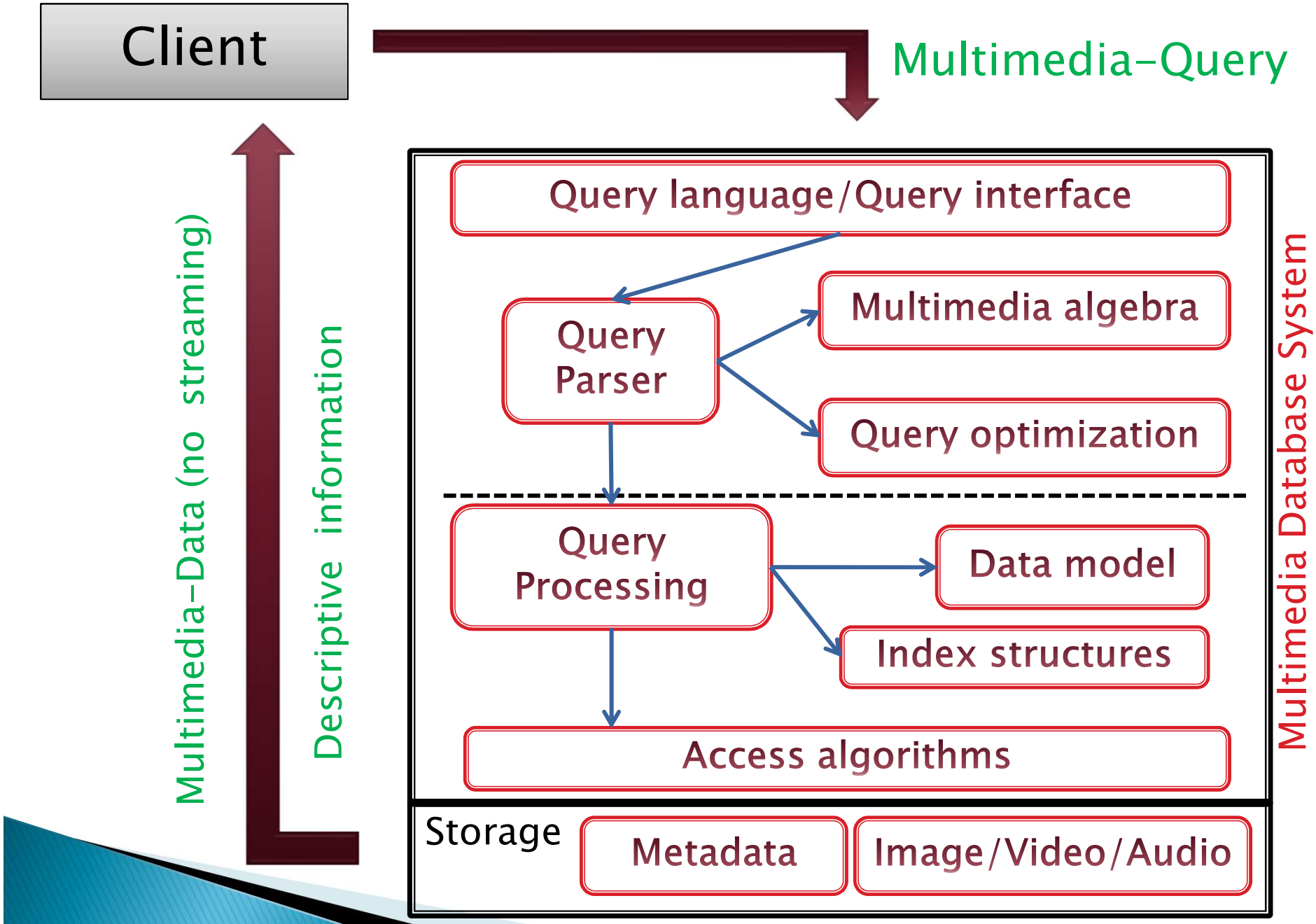
1 Multimedia Definition
2 Multimedia Systems
3 Multimedia – main domains
4 Data streams
5 Types of media
6 Multimedia Databases

Requirements of a MMDBMS

A MMDBMS must provide the following functionalities:

- Storage, Indexing and searching of multimedia objects
- Transparence of all physical aspects
- Search functionality – "Content-based Retrieval and Search"
- Access structures for multimedia- and their descriptive data (metadata)
- "Multi-user access" by "concurrency control"
- "Data consistency"
- "Reliability" by "recovery mechanisms"
- " Cross-Media" and "composite media"
- " Real-time capacities" and " streaming"

Architecture of Multimedia Database Systems


Client
Multimedia-Query
Multimedia-Data (no streaming)
Descriptive information
Query language/Query interface
Query Parser
Multimedia algebra
Query optimization
Query Processing
Data model
Index structures
Access algorithms
Storage
Metadata
Image/Video/Audio
Multimedia Database System

MMDB and Retrieval: What is it ?

First try for a clearer allocation

- Example:

  An insurance company stores the file corresponding to an accident in the form of a multimedia object. The object contains:

  - Pictures of the accident
  - Descriptive forms containing structured text
  - Interviews of the involved parties (audio recordings)
  - Written report of a representative of the insurance company

- Multimedia retrieval systems must retrieve structured and unstructured data

MMDB and Retrieval II

- Retrieval of structured data:
  - is typically managed by a Database Management System (DBMS)
  - The DBMS provides a query language (e.g. SQL)
  - A deterministic matching of query and stored data is conducted

- Retrieval of unstructured data:
  - is typically managed by an Information Retrieval (IR) System
  - Comparison of similarity between query data and stored documents representations; fuzzy matching
  - Result: Ranked list of relevant documents ordered by similarity

MMDB and Retrieval III

- A Multimedia Database Management System should combine both DBMS and IR technologies
  - Best of both worlds: Data modelling capabilities of DBMS + extended and similarity-based capabilities of an IR-system
- Challenge = Finding of a data model that enables:
  - Storage, matching and distribution of structured and unstructured data
- Good candidate = Object-Relational Model
  - Possibility of adding the required functions to a relational database through user defined types and other object-oriented extensions to classical SQL

MMDB and Retrieval IV

- Matching of queries and document representations:
  - Consider the whole set of attributes and their relation in queries and document representations (make use of structured and unstructured attributes and objects)
  - Combine exact matching of structured data with fuzzy matching of unstructured data

- Distribution of data:
  - Browsing and retrieval
  - Time-related restrictions of video and audio presentations must be considered

MMDBMS Queries

1) As in many retrieval-systems the user must be able to browse and navigate the dataset through hyperlinks, using for example:
   - Topic maps (ISO/IEC 13250:2000 standard)
   - Summarization of multimedia objects

2) Queries specify the conditions of the search
   - Multimedia query language:
     - Predicates for expressing conditions on attributes, structure, content and semantics of multimedia objects

MMDBMS Queries II

- Attribute-predicates:
  - concern the attributes of multimedia objects with precise values (cf. traditional DB attributes):
    - e.g. date of an image, name of a show

- Structure-predicates:
  - temporal predicates to specify info related to time synchronization:
    - for continuous media, such as sound and video
    - for the expression of temporal relations
    - e.g. "Find all the objects in which a jingle is running along for the duration of an image"

MMDBMS Queries III

- Spatial-predicates to specify spatial layout properties of multimedia objects:
  - Example predicates: contains, is contained in, cuts, adjoins
  - e.g. “Find all images in which the car is parked next to a tree”
- Temporal and spatial predicates can be combined:
  - e.g. “Find all video segments in which the ball is seen within a goal-box followed by crowd cheering lasting more than 30s”
- Temporal and spatial predicates can:
  - Make reference to whole objects
  - Make reference to subcomponents of objects: on condition that the data model supports complex object representations

MMDBMS Queries IV

- Semantic predicates:
  - Target the semantic content of the data
  - Are represented by features that are extracted and stored for each multimedia object
  - Uncertainty, proximity and significance can be expressed in the query
  - Ex. "Find all videos in which two brothers shake hands"

- Multimedia query language:
  - Structured language
  - Users do not express queries in this language (generally too complex) but describe their information needs through a user-friendly interface
  - Natural language capabilities?
  - The interface translates the user input into a correctly formed query expressed in the MM query language

MMDBMS Queries V

Query by example:

- The user submits an example data item. Its features are extracted and compared to those of the objects of the DB. A ranked list of matching objects is returned.
- e.g. in a graphic user interface (GUI): Users provide an image of a house and select desired features to express the query: “Find all houses with similar shape but different color”

Question-answering

- e.g. Pose questions related to the content of MM objects: “How many birds sit on the tree? ”

…The End