

Chapter 2 - Concepts and Definitions

Introduction and Requirements

Literatur:

Klaus Meyer-Wegener: Multimediale Datenbanken – Einsatz von Datenbanktechnik in Multimedia-Systemen (2. Aufl.), Teubner-Verlag, 2003



Database Systems

- Usage: management of large sets of data
 - well-structured
 - elimination of redundancies
 - flexible query/search support
 - flexible data usage (open for new applications)
 - concurrent data access by multiple applications
 - high data currency
 - fault tolerance
- Key concepts
 - data model and DB schema
 - data modeling (DB design) is a complex, expensive task
 - requires tight cooperation of developer and user
 - normalization
 - query language (selection, join, aggregation, ...)
 - synchronization of data access operations
 - transactions
 - "all or nothing" behavior for a sequence of operations
 - automatic recovery from inconsistent DB-states due to failure



Multimedia Databases as Content Repositories

- What can databases do for managing multimedia data?
 - data independence
 - data structures and DB schemas are application-independent
 - support for storage, search
- Fundamental service
 - infrastructure for a numerous applications
 - focus on APIs, not so much on end-user interfaces
- Storage and retrieval of multimedia objects
- Key concepts (in addition to database concepts discussed above)
 - device- and format-independent access to MM objects
 - representation of relationships
 - among MM objects, between MM objects and structured data
 - used for querying and navigation
 - content-based search
 - descriptive, similarity-based



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Multimedia Management and Retrieval: Challenges

- Data volume
 - storage and management of large objects
 - compression
 - efficient resource management and content processing
- Implicit semantics
 - feature extraction
 - similarity search
- Heterogeneity
 - media object types, formats
 - conversion
- Complex multimedia objects
 - combination of various MM object types
 - management of structural information
- Input/Output devices
 - dependencies regarding media object types
 - optimized data/result delivery
 - real-time aspects and requirements



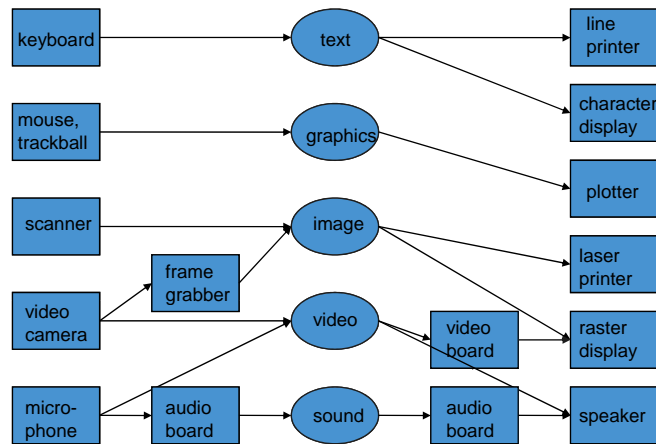
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Multimedia Data

- related to input/output devices:



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Multimedia Data (2)

- comparison:

Medium	Elements	Order	Typical size	Time-dependent?	Sense
Text	printable characters	sequence	10 KB (5 p.)	no	visual/acoustic
Graphics	vectors, polygons, meshes (3D), textures	set or sequence (z-order)	10-100 KB	no	visual
Raster Image	pixel	matrix	1 MB (1024X1024)	no	visual
Audio Recording	amplitude	sequence	600 MB (audio CD)	yes	acoustic
Video-Clip	Raster Image, Graphics	sequence (script)	2 GB (30 min.)	yes	visual



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Multimedia Content - Terminology

- Media Object
 - a data object belonging to a *single* media, e.g., a single image or piece of text
- Multimedia Object
 - (or "Mixed-Mode Object")
 - aggregation (composition) of media objects having different types, z.B. Video (image + audio)
- Multimedia Data
 - generic term for both media objects and multimedia objects
- Multimedia Document
 - aggregates media objects and multimedia objects
 - defines a structure and/or layout (spatial and possibly temporal)
 - may include elements for navigation/browsing (e.g., links)



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Media Object

- consists of structure *and* unstructured data
- raw data
 - unstructured (s. oben)
 - large sequence (set, ...) of small elements (*bits, characters, pixel, lines, ...*)
- registration data
 - mandatory
 - required for correct **interpretation** and **identification** of raw data
 - interpretation: what is the structure? what do the elements mean?
 - identification: to distinguish among otherwise equal objects (e.g., creation/recording timestamp, ...)
- descriptive data
 - optional
 - often redundant: representation of **structure** and/or **content** in a different media or form
 - structured an/or unstructured



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Operations on Media Objects

- Create (insert, capture)
 - from device – in a program – from a file
- Output (show, present)
 - on device – to program – in a file
- Update (modify, edit)
- Compose
 - creation of *multi*-media objects
- Deliver (send)
- Archive
- Process (aggregate, derive)
 - filter, analyse, extract, create descriptive data
- Search (compare)
 - pattern matchin on raw data
 - similarity
 - based on descriptive data



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Example: Raster Image

- Raw data
 - pixel matrix (pixel = picture element, or "pel")
- Registration data
 - # of bits/pixel (pixel depth, usually 1, 8, or 24)
 - # of pixels/line (picture width)
 - # of lines (picture height)
 - linearization: by line or column
 - pixel semantics: grayscale, color definition, index into colormap
 - (optional) colormap with specific number of entries, length of entries (e.g., 24 bit)
 - (optional) definition of color space (RGB, IHS, ...)
 - and more
- Descriptive data
 - text, keywords, knowledge representation describing content
 - recognized lines, areas appearing in the image
 - resulting 2-D objects such as circles, ellipses, polygons, ...



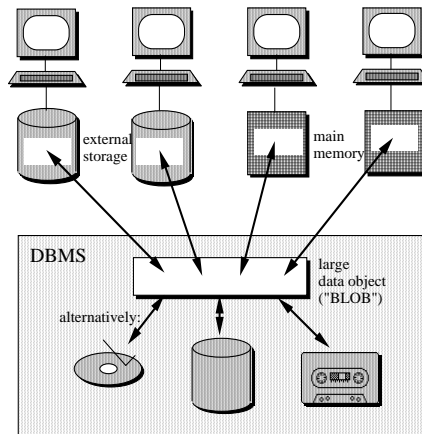
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Device Independence

- Multimedia data volume requires new storage media/devices
 - optical, video tape, ...
- Devices
 - operation of devices differs from hard disk storage
- Data independence required
 - application should be independent from the storage technology used
 - no program changes required when new devices are introduced
- Goal for content repository (MMDBMS)
 - hide all device-specific properties



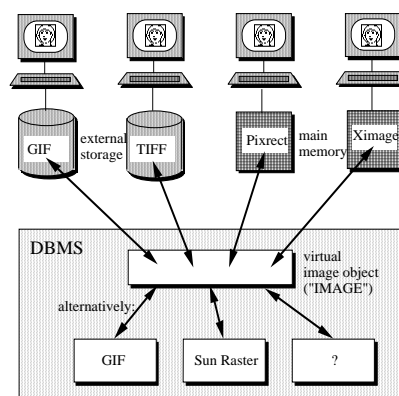
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Format Independence

- Storage formats for media objects
 - numerous formats exist today
 - various "standards"
 - examples (raster images): GIF, TIFF, JPEG, Sun Rasterfile, FBM, PBM, ...)
 - format conversion possible (most of the time)
 - additional aspects: compression, container formats (e.g., AVI)
- Goal for content repository (MMDBMS)
 - hide internal storage format from end users and applications
 - provide conversion routines
 - support change of (internal) storage format (e.g., if new compression techniques become available) without impacting the applications



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Structured vs. Unstructured Data

■ structured data

(NAME = "Miller"; BDATE = "1952-06-23",)

- values of attributes/fields with a fixed name
- maximal length (= finite value domain)
- predetermined (known) semantics
- search: (classical) data retrieval (i.e., query evaluation)

```
SELECT * FROM EMPS WHERE NAME = "Miller";
```

■ unstructured data

"His name is Miller. He was born on June 23rd, 1952."

- arbitrary length
- mostly self-describing
- unknown/weak semantics
- search: information retrieval

Find documents about employees with the name 'Miller'.



Information Retrieval

■ Index: library catalog on a computer

- availability of text documents in electronic format allows for full-text search as additional option
 - search for words appearing in the document

■ Builds on methods of library sciences

- classification (decimal, ACM, ...) – strictly hierarchical
- indexing: assignment of keywords (descriptors), which describe the semantics of the document (may not even appear in the text)
 - descriptors may be weighted

■ Use of a thesaurus (keyword "dictionary")

- lists all keywords used for indexing
- defines relationships among keywords
 - synonyms (DBS, database system, ...), preferred term
 - broader and narrower terms

■ Manual thesaurus construction and text indexing

- expensive, result influenced by human interpretation

■ Automatic indexing

- input: text document (complete, or abstract/title), thesaurus
- output: keywords (index terms)
- challenges
 - handling linguistic variations, use of synonyms
 - recognizing related words in keyword phrases
 - "DB-design"
 - "the design of high-quality database schemas is ..."
 - "... are DBs. Their design is ..."

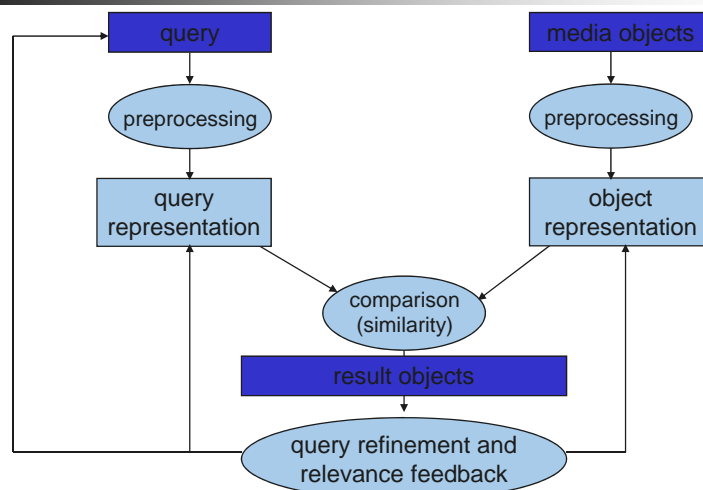


Information Retrieval (2)

- Query
 - consists of keywords, which may be weighted
- Result documents
 - boolean decision whether a document matches the query or not is often inadequate
 - better: similarity score as a measure for describing the **relevance** of the document wrt. the query
- Retrieval model defines how relevance values are determined
 - boolean, vector-based, probabilistic, ...
- Presentation of search results
 - ranking (sorted descending based on relevance)
- Improving query results
 - iterative query process
 - relevance feedback



Information Retrieval Process



Data Retrieval vs. Information Retrieval

- DBS
 - search based on exact match, result always relevant/ complete
- IRS
 - index terms only provide a partial, ambiguous characterization of a document
 - search based on similarity measures, result may contain irrelevant documents

Characteristic	Data Retrieval	Information Retrieval
Information	explicit (attribute values)	implicit (interpretation required)
Results	exact (equality)	approximate/imprecise (similarity)
Query process	single query	iterative refinement
Query formulation tolerance	no	yes
Result collection	set	list (ranked)



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Searching for Media Objects

- Specification of search criteria
 - using properties (features, formatted)
 - verbally (unformatted)
 - query-by-example, using a comparison object (pattern)
- Media objects are usually linked to formatted data
 - application-specific (e.g., archiving number)
 - registration data
 - descriptive data (if formatted)
- Search mechanisms initially based on
 - searching formatted data (classic DB techniques)
 - pattern matching
 - using raw data (e.g., full text search), or
 - using descriptive (unformatted) data



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Content-based Search

- Search based on media object content at a higher level of abstraction
 - objects, activities, situations, etc. represented or described by the media object
 - requires analysis and interpretation of raw data, content
 - hard to do, can only be partially automated
- Examples
 - search for:
 - entries in criminal database using descriptions by crime scene witnesses
 - symptoms of medical conditions in x-ray images
 - satellite images showing an airport
 - news pictures showing Angela Merkel with George W. Bush
 - text documents about digital libraries
 - radio programs about benefits of highway speed limits
 - almost impossible to do based on pattern matching!
- Application and generalization of information retrieval concepts and approaches!



Content-based Search (2)

- Preselection
 - use categories, classification scheme of a content repository (e.g., relations in an RDBMS)
 - helps reduce the search scope, but usually too coarse-grained
- Content analysis at runtime
 - for a specific query
 - methods and techniques for
 - text analysis and indexing
 - image processing/recognition
 - speech recognition
 - to be applied to a (large) set of media objects
 - too expensive!
- Browsing
 - fast browsing through preselected search scope
 - puts burden of search evaluation on the end user
 - only feasible for small sets of objects



Content-based Search (3)

- Consequence: **Content analysis as a pre-processing step**
 - creation of content description
 - automatically, if possible (e.g., automatic abstracting)
 - manually: e.g., author or librarian creates a summary, assigns keywords
- Drawback: search criteria at runtime are restricted to those aspects covered by the analysis, cannot be expanded dynamically
 - storage of content description together with the media objects, utilization at query processing time



Representation of Metadata / Content Description

- Formatted Data
 - e.g., as tuples in RDBMS tables
 - efficient search
 - may result in "undesirable" entity types (e.g., "storm", "night", ...) for detailed model of content domain
 - not powerful enough
- Keywords
 - well-known (libraries, IR)
 - easy to create (also automatically)
 - not powerful enough: relationships, dependencies, causalities (e.g., for complex description of image content) are hard to represent
- Knowledge Representation
 - logic, sem. networks, frames, scripts, ontologies, ...
 - search techniques exist
 - powerful, but required expert user (knowledge engineer) to create
- Free text
 - easy to create
 - full text search? dependency on formulations used
- Captions
 - restricts natural language syntax
 - still easy to create
 - may internally be translated to a formal representation (e.g., knowledge representation)



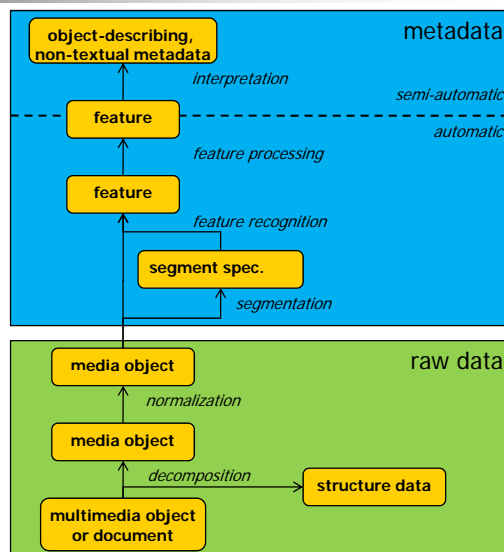
Alternative Classification of Metadata

- content-describing (interpreting)
 - expresses semantics of media object at a high level of abstraction*
 - context-describing (e.g., index vocabulary, ontology, thesaurus)
 - describe context of a collection of objects*
 - context-related (e.g., identification, spatial/temporal coordinates)
 - describe object in relation to a collection of objects*
 - object-describing, non-textual (e.g., objects, people, activities, title)
 - object-describing, textual (e.g., annotation, subtitles, script, screenplay)
- content-related (non-interpreting)
 - properties at a low semantic level, can be extracted automatically*
 - feature (e.g., image color distribution, texture)
 - segment specification (e.g., start/end of video scene, shape of image segment)
- content-independent
 - important for management, correct interpretation*
 - presentation-related (e.g., QoS, resolution, layout)
 - recording-related (e.g., copyright owner, recording device)
 - storage-related (e.g., media type, format, storage location)



Deriving Metadata at Various Abstraction Levels

- Automatic steps
 - decomposition into elementary media objects
 - normalization for internal processing
 - segmentation based on semantics (e.g., image segments, video scenes)
 - type-specific feature recognition
 - feature processing for scaling, normalization of features



Multimedia Database Techniques

- Introduction of (elementary) data types
 - TEXT, GRAPHIC, IMAGE, SOUND, VIDEO,with functionality (→ abstract data types, userdefined types)
- Extension of existing data models
 - relational model (as domains)
 - object-relational, object-oriented model (as UDTs, classes)
- Usage of existing modeling constructs
 - relations/classes
 - attributes/instance variables
 - primary keys, object identifiers
 - methods, inheritance, ...
- Extensions of query languages
 - relational algebra, SQL



Interfaces and Functionality

- Compared to traditional DBMS, programming interface differs from interactive interface
 - view image vs. analyze image in an application
 - in traditional DBMS, the query language is the common interface
- Example: RDBMS, extended with new data types IMAGE, TEXT, GRAPHICS, SOUND etc.

```
create table Person
  (Name char(30),
   . . . . ,
   picture      Image,
   fingerprint  Image)
```

- Access functions for the data type:
 - dependent on the type of interface



Programming Interface

(using extended SQL)

- Read a fingerprint to analyse it in the application:

```
select fingerprint.height(), fingerprint.width()
into :height, :width
from Person
where Name = "Miller";
```

(allocation of memory for the image)

```
select fingerprint.pixelmatrix()
into :pixel
from Person
where Name = "Miller";
```

(work on pixel matrix)



Programming Interface (2)

- direct display:

```
exec sql
select fingerprint.display(:window) into :error
from Person
where .... ;
if ( error!= 0 )
.... ;
```

- write to file:

```
exec sql
select fingerprint.toFile(:file) into :error
from Person
where .... ;
if ( error != 0 )
.... ;
```

- "side effects" in SQL statements



Interactive Interface

- Same example:

```
select fingerprint
  from Person
  where Name = "Miller";
```
- Result is a table displayed on the screen
 - special character or icon to indicate value of type IMAGE
 - mouse-click or special command to display image on separate screen
 - (other approaches are possible)



Summary

- Different types of multimedia data
 - media object, MM object, MM document
 - raw data vs. metadata
- Classification of metadata
 - based on representation
 - based on content aspects
 - registration data vs. content description
 - content-independent, content-related, content-describing
- Requirements for storage and retrieval of multimedia objects
 - handling structured and unstructured data
 - device- and format-independent access to MM objects
 - representation of relationships
 - among MM objects, between MM objects and structured data
 - used for querying and navigation
 - content-based search
 - descriptive, similarity-based
- Overview of information retrieval and content-based search approaches

