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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

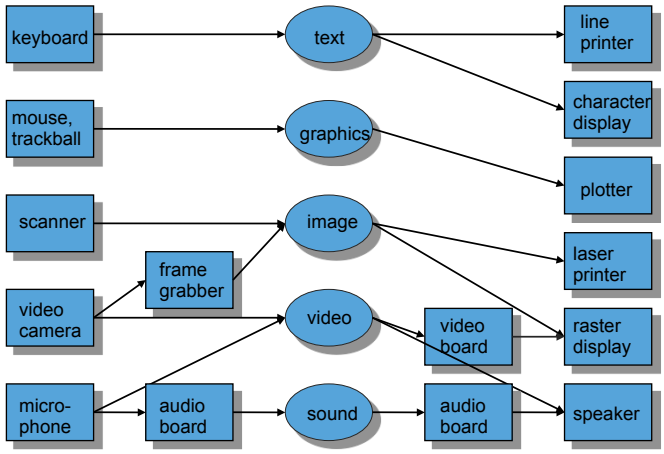
- What can databases do for managing multimedia data?
  - data independence
  - data structures and DB schemas are application-independent
  - support for storage, search
- Fundamental service
  - infrastructure for numerous applications
  - focus on APIs, not so much on end-user interfaces
- Storage 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

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

Multimedia Data

- related to input/output devices:



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

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)

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

Operations on Media Objects

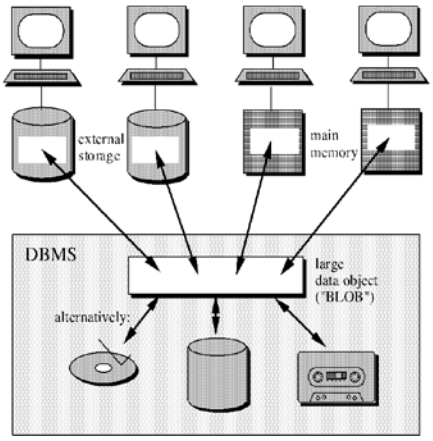
- Create (insert, capture)
  - from device – in a program – from a file
- Output (show, present)
  - on device – to program – in a file
- Update (modify, edit)
- Compose
  - creation of *multi*-media objects
- Deliver (send)
- Archive
- Process (aggregate, derive)
  - filter, analyse, extract, create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

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, elipses, polygons, …

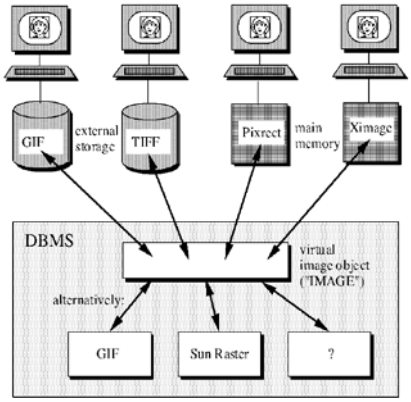
Device Independence

- Multimedia data volume requires new storage media/ devices
  - optical, video tape, …
- Devices
  - operation of devices differs from hard disk storage
- Data indepence 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



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



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'.`

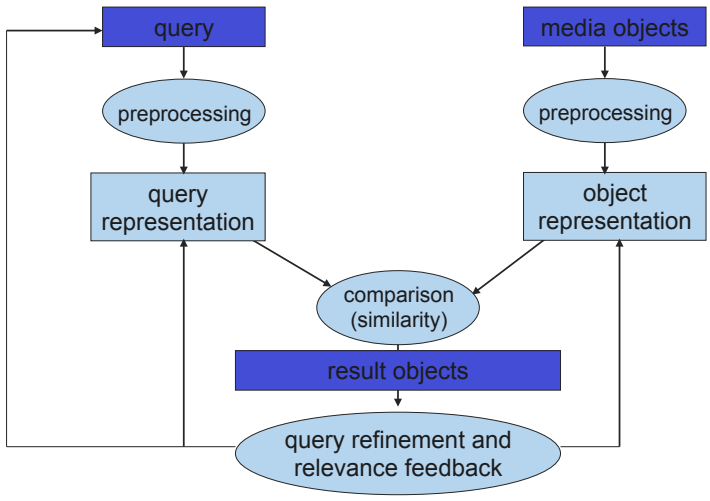
Information Retrieval

- 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)

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

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

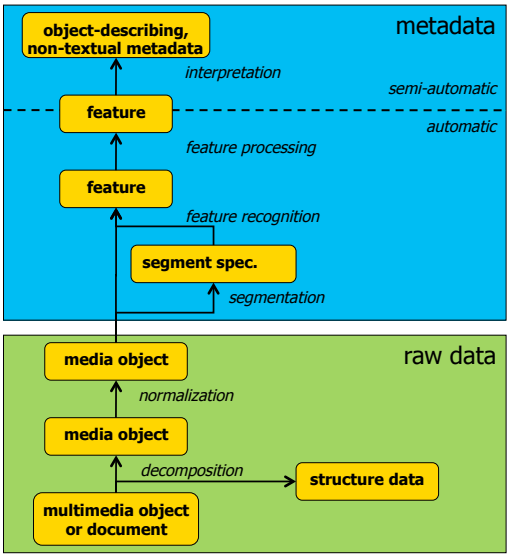
- Formatted Data
  - e.g., as tuples in RDBMS tables
    - efficient search
    - may result in "undesirable" entity types (e.g., "storm", "night", …) for detailed model of content domain
    - not powerful enough
- Keywords
  - well-known (libraries, IR)
  - easy to create (also automatically)
  - not 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