Multimedia Database Systems
Database Systems and WWW

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Literature: Elmasri & Navathe, Fundamentals of DBS, 2000, Chapter 27
(epecially sections 27.1, 27.2 and 27.6)

Internet Application Architecture: Today

Internet Applications

• Entertainment
  – Games, Music, Films, Multi-person chat
• Public information
  – Maps, Tax return helper
• Advertisement
  – Interactive catalogues for products and services
• Medicine
  – Diagnosis, Consultation, Remote surgery
• Education
  – Learning-on-demand (for a degree), virtual museums, tour remote spaces
• Engineering
  – Collaborative design, remote parallel simulation services
• Publishing
  – Submit, Review, Proof-editing (text and graphics)
• Tele-communication
  – Conferencing
• ...
Definition

- Multimedia (MM): loosely; any system that can be used to present information in more than one form: text, graphics, still images, animation, sound, video, special computer-generated effects.

The system should have user-friendly interactive interfaces that help the communication of complexly structured data.

- MMDBSs: are the DBSs that manage MM data, facilitate MM for presentations, and use specific tools for the storage, management, and retrieval of MM data.

Multimedia-Supported Learning of Practical Medical Procedures

- Provide realistic visualization of required practical skills
- Proven to be pedagogically beneficial to view the multimedia lesson on a procedure in a "learning on demand" setting before observing it in the clinic
- Lessons involve realistic multimedia elements (video and audio) recorded in Oslo hospitals, with expert commentary,
- Over 17,000 multimedia elements in OKSE-basen database.
- Mostly on CD-ROM.
- LoD over the Internet would enable
  - Greater flexibility (time and location) for students
  - Other applications
    - Paramedics review skills on demand in emergency situations
    - Doctors take courses in their office for lifelong learning
  - Incremental release and revision of lessons or skill segments

Data Flow for a Multimedia Network Server

Selective Multimedia Quality is Critical

- Quality of Service (QoS):
  - The collective effects of service performance which determine the degree of satisfaction of a user of the service.
  - Performance, not operation (non-functional requirements, independent of functional requirements)

- Video accuracy, for example, when draining the chest.
  - The video must accurately show location of arteries, ribs, where the drain can safely be inserted to avoid arteries.

- Audio fidelity, for example, when breathing is difficult.
  - The audio must be clear enough to differentiate between stridor, an obstruction of the large airways, and asthmatic breath sounds.

- Timing accuracy.
  - Some procedures should be viewed in near real time, possibly at reduced video resolution and reduced audio fidelity.

- The critical quality focus may shift within a lesson.
  - The infrastructure should shift resources to the critical qualities (and ignore others if necessary).
Use Case Model

- A Use Case specifies a sequence of actions that the system can perform and that yields an observable result of value to a particular actor.
  - A “use case” is a story of how an actor achieves its goal using the system under design.
  - The purpose of a use case is to define a piece of coherent behavior without revealing or dictating the internal structure of the system.
  - A use case model structures a system's use cases, representing its requirements and interface behavior to serve as input to its designers and implementers.

Main MSLoPP Use Cases

- Record multimedia elements
- Produce a lecture (a skills lesson, a presentation)
- View a lecture

Use Case 3. View a lecture
Goal: A medical student reviews a procedure over the internet, with acceptable QoS.
Comments: The skills lab is linked to the LoD server by an 155 Mbyte/second ATM Network
Scenario: A student goes to the skills lab at the medical school and starts an internet browser.
(Alternatively, the student could connect to the internet from home.) The student logs in to the MSLoPP LoD server, then finds and selects the lesson on draining the chest. Then the system accesses the multimedia database for the selected lesson to determine what multimedia elements are to be included, what resources are required and what levels of QoS should be used to present the lesson. The system confirms that the student's environment has adequate resources for playing the presentation. Then the system sets up the environment and starts playing the presentation. The student views the procedure, using pause, rewind, and play controls to review and replay key parts of the lesson, such as the location of the insertion point relative to the ribs and arteries. The student logs off from the LoD server, ending this use case.

Other Requirements: The LoD server must be able to detect the multimedia software available on the viewing station, and determine the QoS capabilities of the software and the viewing environment. The student must be able to follow the focus to the emphasized elements of the presentation. Timing critical elements must be presented in near real time. Concurrent elements specified to be synchronized must be presented in synchrony.

Requirements for MMDBSs

Ability to ...
- represent arbitrary data types and specification of programs that interact with arbitrary data sources;
- query and modify (update, insert, delete) MM data; including retrieval of MM data via associative search within MM data (minimally, text);
- specify and execute abstract operations on MM data, e.g., play, fast forward, pause, and rewind one-dimensional data like audio or text; to display, expand, and compress two-dimensional data like bit-mapped images;
- deal with heterogeneous data sources in a uniform manner; this includes access to data in these sources and migration of data from one data source to another.
Requirements - 2

MM data storage and retrieval:
- MM & object-oriented data modeling concepts;
- management of several kinds of magnetic and optical storage devices appropriate for MM data handling;
- uniform management of very large data volumes => management of tertiary storage and multi-level storage hierarchies;
- support for realtime data processing => appropriate scheduling and resource allocation techniques;
- support for storage and processing parallelism (performance requirements);
- support for distribution => appropriate distributed DBMS concepts.

Requirements - 3

Realtime and synchronization issues:
- "soft" realtime transfer requirements
- "hard" transaction deadlines
- synchronization between different data streams (data types)
- user interactions (synchronous and asynchronous)

=> dependent on data distribution, storage devices, compression techniques for the various data types, buffer management techniques, scheduling algorithms, data placement techniques, and communication bandwidth

Storage space requirements for uncompressed digital multimedia data (examples)

<table>
<thead>
<tr>
<th>Media type</th>
<th>Specifications</th>
<th>Data rate per sec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voice-quality audio</td>
<td>1 channel, 8-bit samples at 8 kHz</td>
<td>64 Kbits</td>
</tr>
<tr>
<td>MPEG-encoded audio</td>
<td>Equiv. to CD quality</td>
<td>384 Kbits</td>
</tr>
<tr>
<td>CD-quality audio</td>
<td>2 channels, 16-bit samples at 44.1 kHz</td>
<td>1.4 Mbits</td>
</tr>
<tr>
<td>MPEG2-encoded video</td>
<td>640x480 pixels/frame, 24 bits/pixel</td>
<td>0.42 Mbytes</td>
</tr>
<tr>
<td>NTSC-quality video</td>
<td>640x480 pixels/frame, 24 bits/pixel</td>
<td>27 Mbytes</td>
</tr>
<tr>
<td>HDTV-quality video</td>
<td>1280x720 pixels/frame, 24 bits/pixel</td>
<td>81 Mbytes</td>
</tr>
</tbody>
</table>

DBMS Concepts

- Data modeling: temporal object-oriented modeling and presenting (HCI) of multimedia data + extra data types & operations
- Query processing and optimization: browsing, content addressing
- Storage management: optimization techniques
- Transaction management: realtime processing for read transactions (presentations), write transactions (authoring) use a advanced transaction model (e.g., checkout-checkin with versioned data)
User Interface Design for MM Applications

- User interaction and user interfaces become much more complex if MM data is involved.
- State-of-the-art: buttons, text entry, scrollable areas, ... -> does not support interaction with continuous media
- New devices (e.g., cameras, microphones, loudspeakers, ...) have to be taken into account in addition to keyboard, mouse, monitor, and external devices (e.g., VCRs, ...) for input and output handling:
  - simultaneous control of different devices
  - efficient handling of user interrupts
  - standardized interaction paradigms
  - support for pen + voice input
  " ..."

Object-Oriented Data Modeling + ...

Data types and operations for:

- text
- graphic
- image
- audio
- speech
- video
- generated media

Temporal relationships:
- Synchronization and realtime processing

Quality-of-Service:
- to handle average delay, speed ratio, utilization, jitter, skew, and reliability.

Required Data Model Concepts and Related Work

- Time independent data types
- Time dependent data types (continuous types)
- Temporal concepts: valid, transaction, and play time
- Temporal data models: TIGUKAT, T_Chimera, Mediadoc, SGML/HyTime, ...
- Multimedia data models: AMOS, SGML/HyTime, LMDM, ...

Concepts of TOOMM
Example: Modeling a Video Object

![Diagram of a video object model]

Type Hierarchy

![Diagram of the type hierarchy]

Components of a stream multimedia object

![Diagram showing components of a stream multimedia object]

Play Time

![Diagram showing play time components]

Components of a CGM multimedia object

![Diagram showing components of a CGM multimedia object]
Example: Using Temporal References

Recursive temporal reference list

Reference: True deviation: 0 
time_point: NA

Reference: True deviation: -5 
time_point: NA

Reference: True deviation: NA 
time_point: 15

Building Multimedia Presentations

Video

Start

Stop

P_start

P_stop

CPO
Query Processing and Optimization

- **Browsing:**
  efficient location of data elements in very large amounts of data, exact-match (pattern-matching) queries (e.g., text) and similarity-based queries (e.g., images, ...)
  -> query refinement
  -> set-oriented and navigation-oriented browsing techniques

- **Content addressing:**
  efficient location of data with complex data types like images (difficult to access in realtime using pattern-recognition techniques)
  comprises: natural language understanding, speech processing, vision, and user modeling

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**Meta-Data Management**

- Meta-data needed especially for continuous data to support retrieval
- Textual data describing contents of audio and video segments
- Content search mostly performed on meta-data

  - **Problems:**
    - Modeling of meta-data
    - Meta-data acquisition
    - Association of meta-data to “real” data

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**Storage Management Issues**

- addressing techniques
- access paths
- data placement techniques: clustering, partitioning, allocation
- system buffer management: paging, ...
- disk scheduling: sweeping, deadline-driven, ...
Data Placement

- Clustering and partitioning:
  - data striping and data interleaving

- Allocation:
  - contiguous placement
  - constrained placement
  - log-structured placement

Disk Scheduling

- Traditional algorithms
  - FIFO (first come, first served)
  - SSTF (shortest seek time first)
  - SCAN (elevator algorithm)

1. Generation MM algorithms
  - EDF (earliest deadline first)
  - SCAN-EDF
  - GSS (grouped sweeping scheme)

2. Generation MM algorithms
  - two-phase algorithms

MMDBS: Conclusions

- investigated functionality needed to support MM applications
- illustrated how object-oriented and other modern DBMS technologies can be applied to realize MMDBMS
- alternative “levels” of application support by DBMS
- open issues:
  - effective storage models
  - MM query languages and processing techniques
    (handling of imprecise queries)
  - ...
- Role of (MM)DBS in distributed MM systems

Conclusions - State-of-the-Art

- Multimedia file systems and multimedia storage servers for special multimedia applications exist today
- Implement the presented concepts
- Acceptable performance
- Multimedia database systems are still under development, certain aspects are solved
- Retrieval problems not yet solved in a satisfying manner