Multimedia Storage Techniques

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Objectives of the Talk

• Understand the characteristics of the multimedia data.

• Know the storage requirements of the multimedia data.

• Learn the existing storage structures of video, audio, image data.

• Understand the MPEG standard.

• Study the MPEG2 storage techniques.

• Know the digital image storage formats.

• Build heterogeneous multimedia document storage structures.

• Familiarity of physical storage devices for multimedia data.
### Media and Storage Requirements

- **Characteristics of multimedia data**
  - Multimedia data tends to be voluminous.
  - Second, continuous media data, such as video and audio have timing characteristics associated with them.

<table>
<thead>
<tr>
<th>MIS</th>
<th>Media Data</th>
<th>Size</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medicine</td>
<td>Digital Chest X-Ray</td>
<td>1,024b x 1,024b x 12b/pixel</td>
<td>13 Mb</td>
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<tr>
<td></td>
<td>X-Ray Computed Tomography</td>
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<td>512b x 400b x 8b/pixel</td>
<td>1.8 Mb</td>
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<td>Motion Video</td>
<td>High Resolution (color)</td>
<td>1024b x 1024b x 24b/pixel</td>
<td>25 Mb</td>
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<td>VT100 ASCII Text Screen</td>
<td>80 c/l x 24 l x 8 b/c</td>
<td>16 kb</td>
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<tr>
<td></td>
<td>Page ASCII Text (Courier)</td>
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<td>29 kb</td>
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<tr>
<td></td>
<td></td>
<td>(300pixel/in.)^2 x 24 b/pixel</td>
<td>200Mb</td>
</tr>
<tr>
<td></td>
<td>5s LPC Coded Voice</td>
<td>2.4 kb/s x 5 s</td>
<td>12c kb</td>
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</table>
Multimedia Standards

• A standard implies consistency and conformity, which means they facilitate interoperability and compatibility.

• Factors to consider:

• Lifetime, Portability and Costs

• Standards in computing are developed to solve problems:

  – *Interoperability* – allow systems to communicate with each other (e.g., TCP/IP)

  – *Portability* – allowing software to work on different systems (e.g., Java)

  – *Data exchange* – allowing data to be transferred to different systems (e.g., JPEG)

Factors to consider: **Lifetime, Portability and Costs**
Storage Structures of Video Data

• **Control Information**

• **Frame Rate:**

• Video is made up of 30 (or 24) pictures or frames for every second of video.

• Frames are split in half (odd lines and even lines), to form what are called fields.

• *Interlaced video:* When a television set displays its analogue video signal, it displays the odd lines (the odd field) first. Then it displays the even lines (the even field).

• *Non-Interlaced Video:* Computer monitor uses “progressive scan” to update the screen. Computer displays each line in sequence, from top to bottom.
Storage Structures of Video Data

• Control Information

• Color Resolution:
  - Color resolution refers to the number of colors displayed on the screen at one time
  - RGB (red-green-blue) and YUV (luminance component (the brightness) and U and V chrominance (color) components)

• Spatial Resolution:
  - “How big is the picture?”

• Image Quality:
  - Video should look acceptable for an application.
Video Data Compression

Factors associated with compression

- Real-Time versus Non-Real-Time
  - Some systems compress to disk, decompress and playback video (30fps) all in real time

- Symmetrical Versus Asymmetrical
  - Symmetrical: if a sequence of 640x480 can be played at 30 fps, capturing, compressing and storing is also possible at the same rate.
  - Opposite of Asymmetrical

- Compression Ratios
  - The numerical representation of the original video in comparison to the compressed video

- Lossless Versus Lossy
  - Is there any loss in quality of the compressed image in comparison with the original?
Video Data Compression

• Interframe Versus Intraframes
  - *Intraframe* method compresses and stores each video frame as a discrete picture
  - *Interframe* method: Reference Frame and the differences between frames are recorded.

• Bit Rate Control
  - Parameters such as frame rate, quality of the images should be allowed to be modified w.r.t. the application requirements

• Selecting a Compression Technique
  - Motion JPEG, MPEG-1, MPEG-2, so on up to MPEG-7 and MPEG-2000 are internationally recognized standards for compression of moving pictures.
MPEG Standards

- Video is a sequence of pictures, each picture is consisted by an array of pixels.
- Such as CCIRR-601 parameters (720 pixels x 480 pixels x 30 frames/s), it has a data rate at about 165 Mbps.
- MPEG compression techniques tries eliminate redundant or unnecessary information
- Most video technologies use lossy techniques
- MPEG : Moving Picture Experts Group
MPEG Standards

• Available MPEG standards

• MPEG-1
  - Works on the Medium Bandwidth (up to 1.5Mbits/sec) + 1.25Mbits/sec video 352 x 240 x 30Hz + 250Kbits/sec audio (two channels).
  - Deals with Non-interlaced video.
  - It has been optimized for CD-ROMs.

• MPEG-2
  - Works on the Higher Bandwidth (up to 40Mbits/sec).
  - Handles Up to 5 audio channels (i.e., surround sound).
  - Covers wider range of frame sizes (including HDTV).
  - Can deal with interlaced video.
MPEG Standards

• Available MPEG standards

• MPEG 3
  - designed to handle HDTV signals in the range of 20 to 40 Mbit/s.
  - HDTV resolutions of 1920 x 1080 x 30 Hz

• MPEG 4
  - Very low bandwidth (64 kbits/sec) + 176 x 144 x 10Hz
  - For both TV and WEB
  - Broadcast-grade synchronization
  - Choice of on-line/off-line usage
  - Virtual Reality Modelling Language
MPEG 4 Features

• Ability to efficiently encode mixed media such as video, graphics, text, images, audio and speech (called as audio-visual objects (AVOs))

• Ability to create compelling multimedia presentation by compositing these mixed media objects by a compositing script

• Error resilience to enable robust transmission of compressed data over noisy communication channels

• The ability to encode arbitrary shaped video objects

• Multiplex and synchronize the data associated with these objects, so that they can be transported over network channels providing a QoS appropriate for the nature of the specific objects

• Ability to interact with audio visual scene generated at the receiver end
MPEG 7

- Multimedia Content Description Interface
- Description is associated with the content
- Applications:
  - Digital libraries (image catalogue, musical dictionary)
  - Multimedia directory services (eg. Yellow pages)
  - Broadcast media selection (radio channel, TV channel)
  - Multimedia editing (personalized electronic news service, media authoring)
MPEG 2 - Overview

- GOP
- Pictures
- Slice
- Macroblock
- Block

MPEG 2 Video Stream Data Format
MPEG 2 - Overview

- 4 parts of the Standard:
  - System coding layer of MPEG-2
  - Coding and Decoding of Video
  - Coding and Decoding of Audio
  - Conformance Test

- Aimed at coding CCIRR – 60
MPEG 2 – Video Sequence

- Picture
- Video Sequence
- Group of Pictures

- Picture
- Slice
- Macroblock

- Block

- 8 Pixels
- 8 Pixels
MPEG 2 – Picture Types
MPEG 2 – Picture Types

• Intra Pictures (I-Picture)
  - coded using only information present in the picture itself
  - uses only transform coding and provide moderate compression.
  - Typically it uses about two bits per coded pixel.

• Predicted Pictures (P-pictures)
  - coded with respect to the nearest previous I- or P-pictures.  
    (forward prediction)

• Bidirectional Pictures (B-pictures)
  - use both a past and future picture as a reference (bidirectional prediction)
  - Provide the most compression, computation time is the largest
## MPEG 2

<table>
<thead>
<tr>
<th>Level</th>
<th>Frame size</th>
<th>Maximum</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(PAL/NTSC)</td>
<td>Bitrate</td>
<td></td>
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<tr>
<td>Low</td>
<td>352x288</td>
<td>4 Mb/s</td>
<td>CIF, consumer tape equiv.</td>
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<tr>
<td></td>
<td>352x240</td>
<td></td>
<td></td>
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<tr>
<td>Main</td>
<td>720x576</td>
<td>15 Mb/s</td>
<td>ITU-R 601, Studio TV</td>
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<tr>
<td></td>
<td>720x480</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High 1440</td>
<td>1440x1152</td>
<td>60 Mb/s</td>
<td>4x 601, consumer HDTV</td>
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<tr>
<td></td>
<td>1440x1080</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>1920x1152</td>
<td>80 Mb/s</td>
<td>prod. smpte</td>
</tr>
<tr>
<td></td>
<td>1920x1080</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MPEG 2 - Encoding

- The MPEG-2 transform coding algorithm includes the following steps:
  - Discrete cosine transform (DCT)
  - Quantization
  - Run-length encoding
- Predicted Pictures
- Bidirectional Picture
- Profiles and Levels
- Scalable Modes
- Data Partitioning
- SNR Scalability
- Temporal Scalability
- Interlaced Video and Picture Structures
- MPEG-2 Video Storage Layout
- MPEG-2 Audio
Digital Image Formats

- Thumbnails
Digital Image Formats

• **Tagged Image File Format (TIFF) and CCITT Fax 4 Compression**
  
  - Suited to bitonal text documents
  - Can provide a high level of detail combined with a smaller file size
  - May be used as a master image file format.

• **TIFF with LZW Compression**
  
  - is a 24-bit, lossless (no information lost) compression format, commonly used by Adobe Photoshop and other image editing software
  - Used to store color and grayscale files
  - May be used as a master image file format.
JPEG and GIF

- **JPEG (Joint Photographic Experts Group)**
- Works best on natural images (scenes)
- 24-bit, lossy compression format well-suited for screen viewing and print presentation
- Compression allows for smaller file sizes for faster downloading and the quality is acceptable for most purposes.

- **Graphics Interchange Format (GIF)**
- 8-bit lossless compression format well-suited for low resolution screen display of files.
- GIF and JPEG are most common formats for thumbnail images and graphics
Other Formats

- **PNG (Portable Network Graphic):** A higher-quality replacement for the GIF format

- **PDF (Portable Document Format):** provides a convenient way to view and print images at a high resolution

- **Kodak PhotoCD:** Used to encode image files onto CD-ROMs.

- **MrSID (Multi-Resolution Seamless Image Database):** uses image compression techniques (wavelet compression) to reduce file size with little loss in image quality
Shape based representation of an image

- Each image shape to be stored in the storage is processed to obtain the shape boundary, and boundary points, called *interest points*, are found.

- Machine-vision techniques for shape matching, depth estimation, motion estimation, and so on

- A *feature* to be can be defined as a collection of a few adjacent interest points. Each boundary feature is encoded for a scale, rotation, and translation invariants.

- Given a feature $F$ with $n$ interest points, a pair is chosen to form a basis vector.

- A coordinate system is defined by treating the basis vector as a unit vector along the x-axis. All other interest points of the feature are transformed to this coordinate system.
Shape based representation of an image

Original Image (640 x 480) and its contours

Scaled Image (160 x 120) and its contours

Scaled Image (64 x 48) and its contours
Shape based representation of an image

- Characteristics of common shape description methods:
  - Input representation form
  - Object reconstruction ability
  - Incomplete shape recognition ability
  - Local/global description character
  - Mathematical and heuristic techniques
  - Statistical or syntactic object description
  - A robustness of description to translation, rotation, and scale transformations: Shape description properties in different resolutions.
Shape based representation

- *Index based image storage structure*

- The encoded feature vectors representing the shape boundary features are used to form a feature index for the shape representation. The similarity between two features is defined as the Euclidean distance between the two vectors.

- *Space-Filling Curves of an Image*

- This method has attracted a lot of interest, under the names of N-trees, linear quad-trees, z-ordering, and so on

- Assumption: A finite precision in the representation of each coordinate, say, $K$ bits. The terminology is easiest described in 2-D address space; the generalizations to n dimensions should be obvious. Following the quad-tree literature, the address space is a square, called an image, and it is represented as a $2^k \times 2^k$ array of 1x1 squares. Each square is called a pixel.
Hypermedia is like hypertext, except that the material which you link from and to can be text, graphics, audio, video, animation, or images.
Hyper Media Representation

- The model includes the following types of components:
  
  - **Atomic**: It represents the basic data types, e.g., text and image.
  
  - **Composite**: It is a container for other components, including Composites, and it is used to structure an interface hierarchically.
  
  - **Link**: It establishes relations among components.

- Every component includes a list of Anchors and a Presentation Specification.

  - Anchors allow to reference part of a component and are used in specifiers, a triplet consisting of anchor, component and direction, used in Links to establish relations between the different components of a hypermedia graph.

  - The Presentation Specification describes the way the data is presented in an augmented interface.
HyperMedia – Events

• Anything that happens and that it changes the information that is presented is an event. There are three main types of events as follows:
  
  - Location of user in a space.
  
  - Recognition of an interest point, identified by an optical marker or a RFID tag.

  - User navigation or choice.

• The position of a user in the space can also define an interest point.
Multimedia Metadata Storage Formats

- Multimedia metadata is structured information that describes, explains, locates, or otherwise makes it easier to retrieve, use, or manage an information resource.

- Three main types of metadata:
  - *Descriptive metadata*: describes a resource for purposes such as discovery and identification. Includes title, abstract, author, and keywords.
  - *Structural metadata*: Indicates how compound objects are put together, for example, how pages are ordered to form chapters.
  - *Administrative metadata*: Provides information to help manage a resource, such as when and how it was created, file type and other technical information, and who can access it.
Metadata Functions

• To facilitate discovery of relevant information.

• Resource discovery, metadata can help organize electronic resources, facilitate interoperability and legacy resource integration, provide digital identification, and support archiving and preservation.

• Resource Discovery Metadata serves by:
  - allowing resources to be found by relevant criteria;
  - identifying resources;
  - bringing similar resources together;
  - distinguishing dissimilar resources; and
  - giving location information.
Structuring Metadata

- Metadata schemes (also called schema) are sets of metadata elements designed for a specific purpose, such as describing a particular type of information resource.

- The definition or meaning of the elements themselves is known as the *semantics of the scheme*.

- ASCII Text

- SGML (Standard Generalized Markup Language)

- HTML (HyperText Markup Language)

- XML

- XHTML (Extensible HyperText Markup Language)

- MARC (The MAchine Readable Cataloginge)
Multimedia Object Based Storage Representation

• Three important factors to consider in the representation of multimedia objects in the storage-data models, real-time data and representation of complex objects.

• A multimedia information unit whether complex or simple, that can be presented to a user in the same desirable manner. This information unit may be called as an “object”.

• Salient Features of the Object Manipulation Environment

  • Dynamic Data Semantics:
    • The semantics associated with the data in an object will typically change often over the object's lifetime.
    • It is important to dynamically change the set of functions (operations) associated with an object after it is instantiated.
Multimedia Object Based Storage Representation

- Salient Features of the Object Manipulation Environment

- *Abstract Function Types:*

- Given an image, one usually has a wide range of functions available that can perform a particular image processing operation. E.g. Edge Detection.

- Abstract functions simply define a logical operation, not the implementation, and postpones the binding of the actual implementation until runtime.

- *Inheritance:*

- Given a raw image, two or more users (or applications) might process the same image and obtain different semantic data to be used for different purposes.
Multimedia Object Based Storage Representation

• Salient Features of the Object Manipulation Environment

• Composition:

• Merging of two or more distinct objects into a new object.

• E.g. two independent pictures of the same scene may be merged together to produce additional information about the scene (e.g., the depth of objects in the scene).

• History mechanism:

• An image typically goes through a series of transformations that extract information from the image or compute new information based on the image.
R-Tree Representation

- R-Tree is an extension of the B-tree for multidimensional objects. A spatial object is represented by its minimum bounding rectangles (MBRs).

(a) Three objects

(b) Spatial relations of objects
Heterogeneous Multimedia Standards

- HyTime (Hypermedia/Time-based Structuring Language):

- SGML based hyperdocument structuring language for representing hypertext linking, time scheduling and synchronisation.

- HyTime has five modules, the first is compulsory:
  - the base module provides facilities required by other modules
  - the location address module provides facilities for locating objects in the data
  - the hyperlinks module allows linking elements to be identified and managed
  - the scheduling module allows data elements, locations or links to be scheduled as events within a presentation
  - the rendition module allows data to be modified to a suitable form prior to presentation
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Heterogeneous Multimedia Standards

- MHEG (Multimedia and Hypermedia information coding Expert Group)
- Specification for representation of final form (i.e., non editable) multimedia and hypermedia objects
- Objects define the structure of the presentation in a platform independent way, and provide functionality for real-time presentation, synchronisation and interactivity
- A self-contained architecture – can run in limited resources (memory, computing capability), (E.g. set-top boxes for games machines or home-shopping)
Heterogeneous Multimedia Standards

- Objectives:
  - Interchange - of different media types.
  - Presentation - the media type is identified and appropriate resources used for presentation.
  - Different media types can be grouped into a single presentation.
  - Use minimal resources.
  - Real time interchange and presentation.
Heterogeneous Multimedia Standards

- **Part 1:** MHEG Object Representation, Base Notation (ASN.1). This defines the objects and their behaviour.

- **Part 2:** MHEG Script Interchange Representation, an executable code dedicated to a virtual machine, the SIR (Script Interchange Representation).

- **Part 3:** MHEG Registration Procedures.

- **Part 4:** Support for Base-Level Interactive Applications, to allow the development of an interpreter requiring few resources.

- **Part 5:** Support for Enhanced Interactive Applications, an extension to MHEG-5, adding computing and communication functions with the external environment.

- **Part 6:** Interoperability and Conformance Testing (under development).
Heterogeneous Multimedia Standards

- PREMO (Presentation Environment for Multimedia Objects)
- addresses the creation of, presentation of and interaction with all forms of information using single or multiple media
- provide a standardised development environment for multimedia applications.
- Aims to be able to integrate different media and their presentation techniques into the same framework
- Allows re-use of objects without having to specify entirely new standards.
- Allows implementation of multimedia services over a network.
- Designed to work with existing and emerging standards, (E.g., provides services used to create an MHEG engine).
Heterogeneous Multimedia Standards

- MIME (Multipurpose Internet Mail Extensions)
- Designed to allow multi-media email
- Messages can be of unlimited length, contain multiple objects, binary files, allow multimedia messages
- A MIME message parts:
  - The MIME-Version header
  - The Content-Type header, which species the type of data. This may be: *text, image, audio, video, message, multipart, application.*
  - Content-Transfer-Encoding header, which specifies how the data is encoded.
  - Content-ID and Content-Description – Identify and describe the data
Heterogeneous Multimedia Standards

- Quicktime
- QuickTime is a proprietary format from Apple.
- Originally designed for the Mac, supported on several platforms.
- Composed of three elements:
  - the movie file format media abstraction layer
  - media services
  - The movie format is a container format, which can in fact contain any digital media.
Multimedia Rope Representation

- ROPE gives a heterogeneous or homogeneous multimedia storage structure
- Both control and regular multimedia data storage structures.
- *Frame* is the basic unit of video.
- *Sample* is the basic unit of audio.
- *Strand* is an immutable sequence of continuous recorded audio samples or video frames. Immutability of strands is necessary to simplify the process of garbage collection.
- *Block* is the basic unit of disk storage. Two types:
  - Heterogeneous Blocks and Homogeneous Blocks
Multimedia Rope Representation

Components of Primary Block, Secondary Block and Header Block of a multimedia Rope.

Primary Block[
  sector,  – position of MB on disk
  sector Count  – length of the MB in sectors
]

Secondary Blocks[
  startBlock,  – Block number
  BlockCount  – number of Blocks in PB
  sector,  – position of PB on disk
  sectorCount  – length of PB in sectors
]

Header Block[
  frameRate  – Rate of recording
  secondaryCount,  – Number of secondary blocks
  frameCount,  – Total number of frames
  secondaryArray  – Array of pointers to SB
]
Multimedia Rope Representation

- **Media Strand**: A sequence of Media Blocks (MB)

- MB contains either video frames, audio samples, or both.

- A 3-level index structure permits large strand sizes, and random sizes, and random as well as concurrent access to strands.
  - For each strand, the file system maintains primary indices in a sequence of Primary Blocks (PB).
  - Secondary indices, which are pointers to Primary Blocks, are maintained in a sequence of Secondary Blocks (SB). Header blocks maintain the sequence of secondary blocks information (HB)
  - From Media strands to Multimedia Ropes multimedia data includes information in various forms: audio, video, textual, factory, thermal, tactile, etc.

- Rope is a collection of multiple strands (of same or different medium) tied together by synchronization information.
Multimedia Rope Representation

- Media strands constitute piece of information tied together by inter-media synchronization – multimedia rope.

- Rope contains name of creator, length, access rights, the strand's unique ID, rate of recording, granularity of storage, and block-level correspondence.

- Block-level correspondence information is used to synchronize the start of playback of all the media at strand interval boundaries.
Multimedia Document Modelling

- Integration of the data, that requires both temporal and spatial synchronization of mono media data to compose multimedia documents

- Logical organization of document components is desired to facilitate browsing and searching within and across documents

- Temporal synchronization is the process of coordinating the real-time presentation of multimedia information and maintaining the time-ordered relations among component media
  - process of ensuring each data element appears at the required time and is played out or a certain time period

- Spatial composition describes the assembly process of multimedia objects on a display device at certain points in time
Using XML Technologies

- XML markup consists form elements, processing instructions, marked sessions, comments and entity references.

- Attributes embodied into elements for providing additional information about the stored data.

Correspondence between a multimedia stream and XML markup:
Using XML Technologies

• Representation Model
  - Data concerning the entire multimedia stream, where general information are included, such as metadata, definition of the main presentation window, etc. The used element is named as `header'.
  - Representation of primitive objects and their attributes. The used element is named as `body'.

• Multimedia Document Representation Requirements
  - Hierarchical representation
  - Capability in representing media objects complexity
  - Expansibility
  - Representation of (possibly) existing relations between streams
Using XML Technologies

• Multimedia Document Representation Requirements
  - Representation of (possibly) existing relations between objects
  - Convenient maintenance and retrieval of the content
  - Convenient and quick creation of the content
  - Convenient processing of the content
  - Support of data structural validity
  - Support of different data types
  - Small size of the representation schema

• Setting requirements in describing primitive media objects
  - Identification mechanism
  - Definition of media type and file type
  - Spatio-temporal attributes, Use of Metadata
SMIL 2.0 – XML for Web Multimedia

• Lets authors create simple multimedia simply and add more complex behavior incrementally

• Lets the user tailor content according to characteristics such as language and computing environment

• Is XML and part of the W3C's family of XML-related standards including scalable vector graphics (SVG), cascading style sheets (CSS), XPointer, XSLT, namespaces, and XHTML.
An example SMIL IISc tour presentation
Features of SMIL

• Media Content:
  
  - Integrates existing multiple media into a single presentation. To specify media elements
  
  - Presentations refer to files in other formats
  
  - `<ref>`, `<img>`, `<video>`, `<audio>`, `<text>`, `<animation>`, and `<textstream>`

• Layout:
  
  - Once multiple media items are selected as content, their display must be coordinated in the multimedia presentation.
  
  - Lets the user control how each media object is arranged on the screen and integrated into the overall presentation.
  
  - `<layout>` and `<topLayout>`
Features of SMIL

• *Temporal Composites:*
  
  - Timing elements dominate the hierarchical composition of the document body, `<seq>` and `<par>`

• *Timing:*
  
  - SMIL presentations change over time, with or without user interaction
  
  - This applies to more than just SMIL presentations; SMIL timing constructs are available to other XML-based formats also.

• *Timing Attributes:*
  
  - *begin* (start element at a particular time), *end* (stops an element after start) and *dur* (*duration* for the element to play)
Features of SMIL

• *Linking:*
  - Uses same Web hyperlinking constructs as HTML, also accounts for the impact of timing on user interaction.

• *Adaptivity:*
  - Helps the user tailor content according to characteristics such as language, perceptual abilities, and computing environment. SMIL element for adaptivity is `<switch>`.

• *Modularity:*
  - SMIL is a metalanguage that lets one create other languages
  - By placing constructs into modules, SMIL combines these modules into a profile - a tailored final-form language for multimedia presentation. (E.g. of SMIL profiles: the SMIL 2.0 Language Profile, SMIL Basic, XHTML+SMIL, and animated SVG.)
Storage Media for Multimedia Data

• The limited I/O bandwidth of a CD-ROM requires that data be interleaved including the script and clip files.

• A VFS (Video File Server) uses large blocks (e.g., some systems use 64MB blocks), and stripe data across different disks on different controllers (i.e., SCSI chains).

• Issues addressed in storage management
  - selecting a VFS on which to load a requested video
  - selecting what video objects to remove from a VFS cache
  - Deciding when to replicate a video object in more than one cache, and
  - re-ordering load requests at the TS device.
Placement Strategies

- Scattered Placement
- Interleaving Placement
- Contiguous Placement
- Contiguous Interleaved Placement
- Scattered Interleaved Placement
Physical Placement of MM Data

• Given $2^{n-k}$, disk groups whose degree of synchronization is $2k$. Media Allocation:

• *Random allocation (RANDOM)*: A media block is allocated randomly. *Disjoint allocation*: Media blocks to be synchronized are allocated to disjoint disk groups.
  - Medium per disk group (DIS-MPD)
  - Medium over all disk groups (DIS-MOAD)

• *Tied allocation*: Media blocks to be synchronized are stored on the same disk group.
  - Random placement (TIED-RAN)
  - Contiguous placement (TIED-CON)