Video Search and Retrieval – Overview of MPEG-7 Multimedia Content Description Interface

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Outline

- Objective, goals, requirements and applications, basic components of the MPEG-7 standard
- Systems tools and Description Definition Language
- Multimedia Description Schemes
- Visual Tools
- Audio Tools
- Relation with other standards

Motivation

- 300 million photos uploaded per day

- 60 hours of video uploaded every minute,
- more than 3 billion views per day,
- over 3 billion hours of video watched each month

Motivation

- **The multimedia context:**
  - More information is in digital form and is on-line
  - AV content covers: still pictures, audio, speech, video, graphics, 3D models, etc.
  - AV content is available at all bitrates and on all networks.
  - Increasing number of multimedia applications, services.

- **Necessity of describing content:**
  - Increasing amount of information.
  - More needs to have “information about the content”.
  - Difficult to manage (find, select, filter, organize, etc) content.
  - User: human or computational systems.

Visual information retrieval

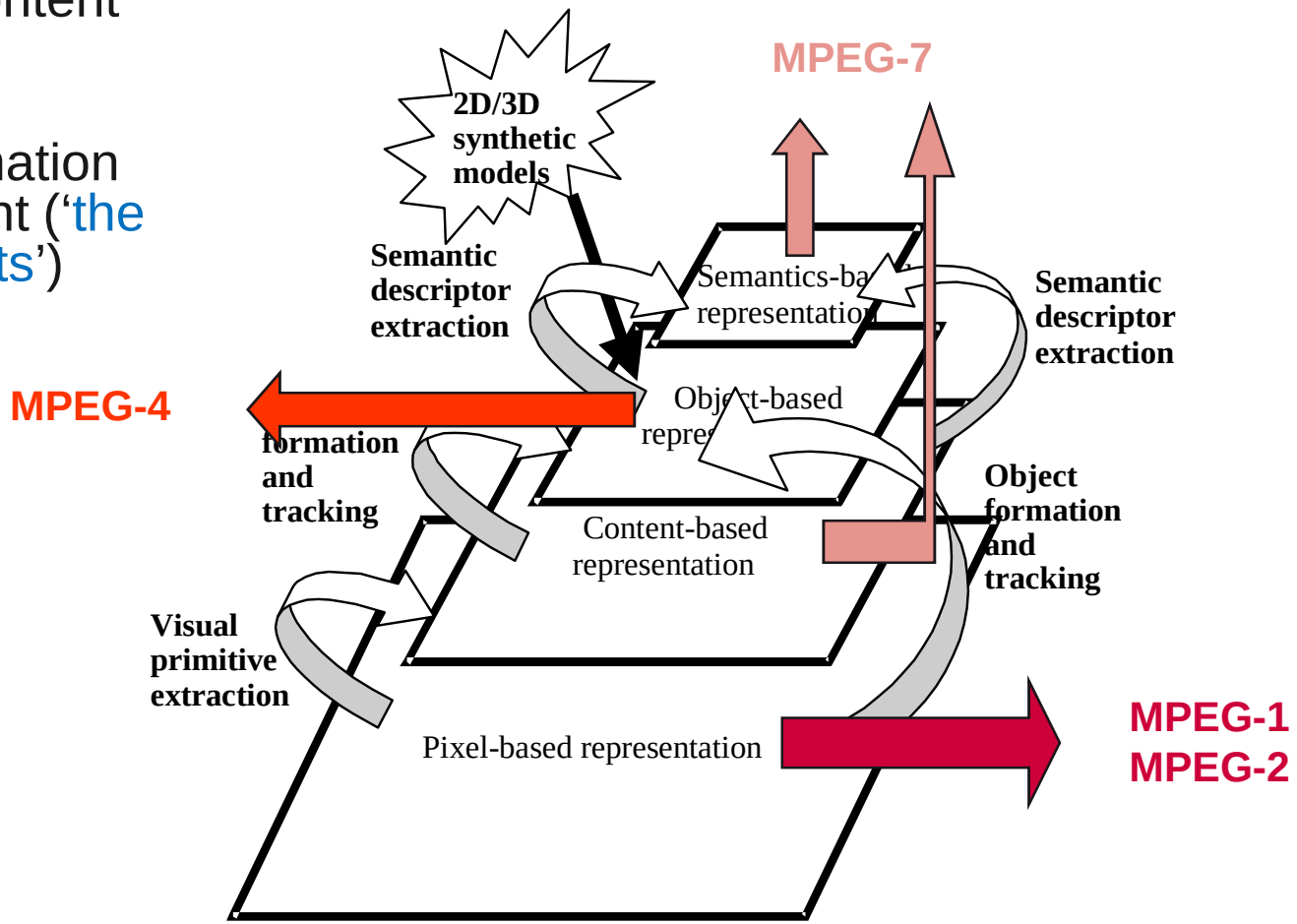
- **Manual/automatic annotation**
  - Assign keywords to an image
  - Multi-class classification by machine learning
- **Content-based image retrieval (CBIR)**
  - Based on the content of the image
  - Image analysis to extract (high-dimensional) feature vectors
    - Color, texture, shape
    - Motion, shot detection, camera operation
  - Low-level versus high-level features: bridging the semantic gap
- **MPEG-7**
  - Standardized content-based description

MPEG Standards

- **MPEG-1 – ISO/IEC 11172 (1993):**
  - Coding of moving pictures and associated audio for digital storage media at up to about 1.5 Mbit/s
- **MPEG-2 – ISO/IEC 13818 (1995):**
  - Generic coding of moving pictures and associated audio information
- **MPEG-4 – ISO/IEC 14496 (1999):**
  - Coding of audio-visual objects
- **MPEG-7 – ISO/IEC 15938 (2002):**
  - Multimedia content description interface
- **MPEG-21 – ISO/IEC 21000 (2001):**
  - Multimedia framework

Data representation pyramid

- MPEG-1, -2 and -4 represent the content itself (‘the bits’)
- MPEG-7 should represent information about the content (‘the bits about the bits’)



Objective of MPEG-7

- **Standardize content-based description for various types of audiovisual information**
  - Enable fast and efficient content searching, filtering and identification
  - Describe several aspects of the content (low-level features, structure, semantic, models, collections, creation, etc.)
  - Address a large range of applications ($\Rightarrow$ user preferences, universal media access)

Types of audiovisual information:

Audio, speech

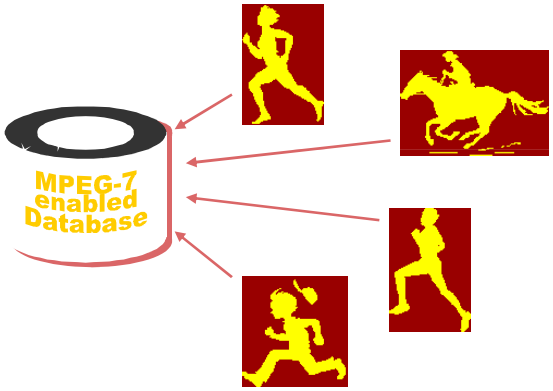
Moving video, still pictures, graphics, 3D models

Information on how objects are combined in scenes

Type of applications

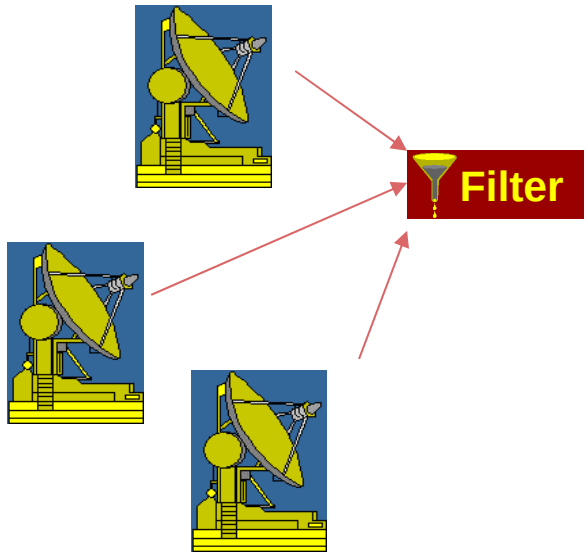
Pull Applications: “Search /Browsing”

Example: Search engines for Internet and databases



Push Applications:“Filtering”

Example: Broadcast of video, Interactive TV



- **Universal Multimedia Access: Adapt delivery to network / terminal characteristics**
- **Specialized Professional and Control Applications**

Example of application areas

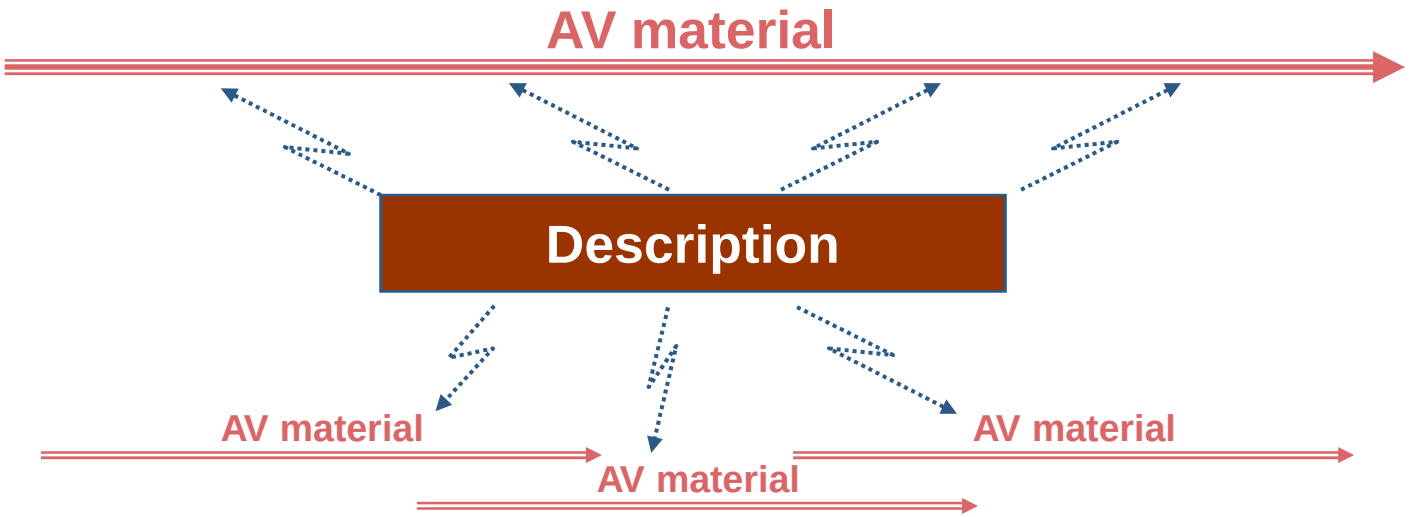
- Storage and retrieval of audiovisual databases (image, film, radio archives)
- Broadcast media selection (radio, TV programs)
- Surveillance (traffic control, surface transportation, production chains)
- E-commerce and Tele-shopping (searching for clothes / patterns)
- Remote sensing (cartography, ecology, natural resources management)
- Entertainment (searching for a game, for a karaoke)
- Cultural services (museums, art galleries)
- Journalism (searching for events, persons)
- Personalized news service on Internet (push media filtering)
- Intelligent multimedia presentations
- Educational applications
- Bio-medical applications

Example of queries

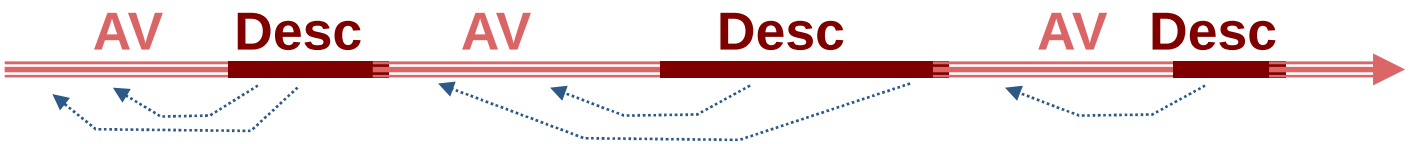
- **Text (keywords):**
  - Find AV material with subject corresponding to some keywords
- **Semantic description:**
  - Find AV material corresponding to a specified semantic
- **Image as an example:**
  - Find an image with similar characteristics (global or local)
- **A few notes of music:**
  - Find corresponding musical pieces or movies
- **Low level features (example: motion):**
  - Find video with specific object motion trajectories

Relation content / description

- Description may be separated from the content



- Description may be multiplexed with the content



Type of description

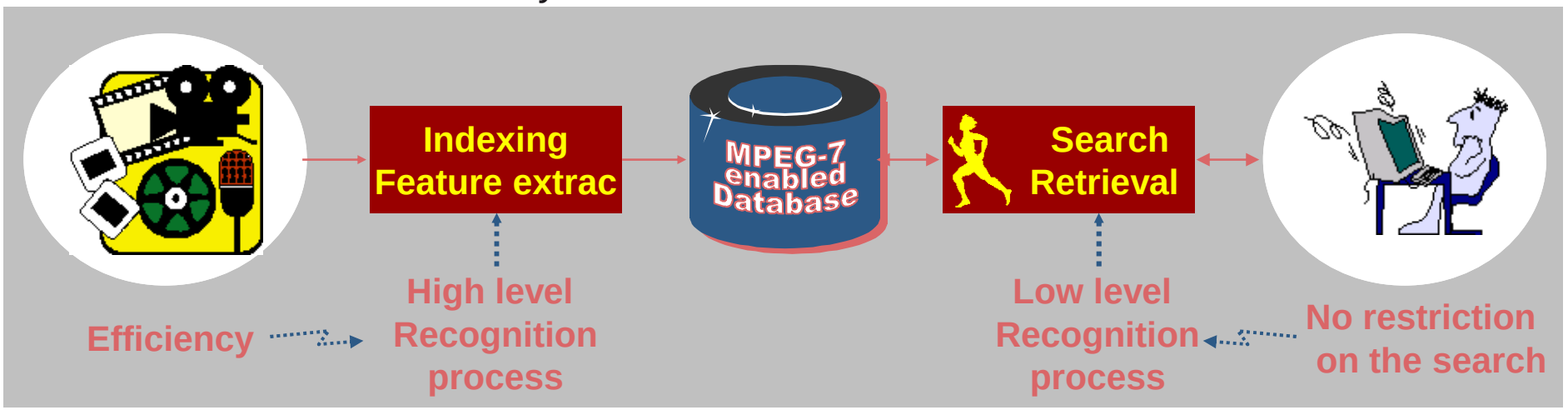
- **Information about the content:** **recording date & conditions, title, author, copyright, coding format, classification etc.**
- **Information present in the content:** **combination of low level and high level descriptors**

High level description:

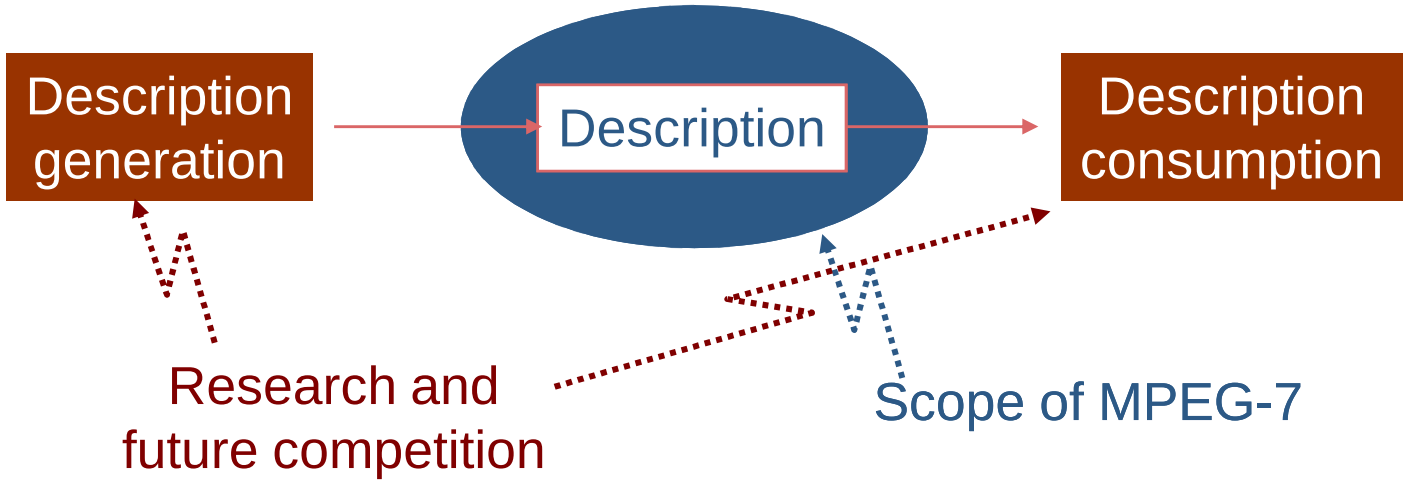
- Efficient and powerful
- Lack of flexibility

Low level description:

- Generic and flexible
- Intelligent / efficient search engine

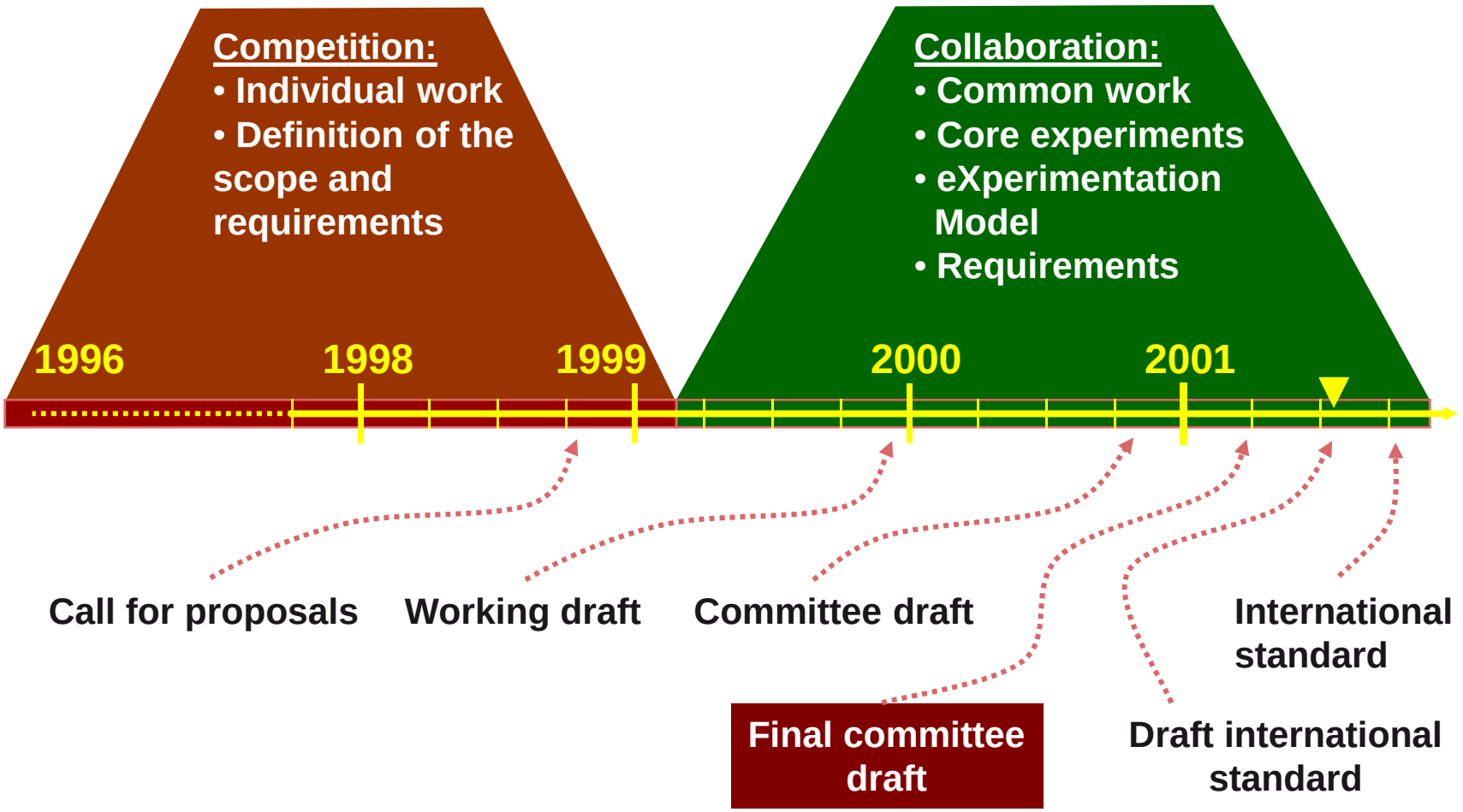


Scope of MPEG-7



- **The description generation (feature extraction, indexing process, annotation & authoring tools,...) and consumption (search engine, filtering tool, retrieval process, browsing device, ...) are non normative parts of MPEG-7.**
- **The goal is to define the minimum that enables interoperability (syntax and semantic of description tools).**

MPEG-7: The Workplan



Information Flow

Feature extraction

Manual / automatic

AV Description

Storage

Decoding (for transmission)

Search / query

Pull

Browse

Conf. points

Transmission

Encoding (for transmission)

Filter

Push

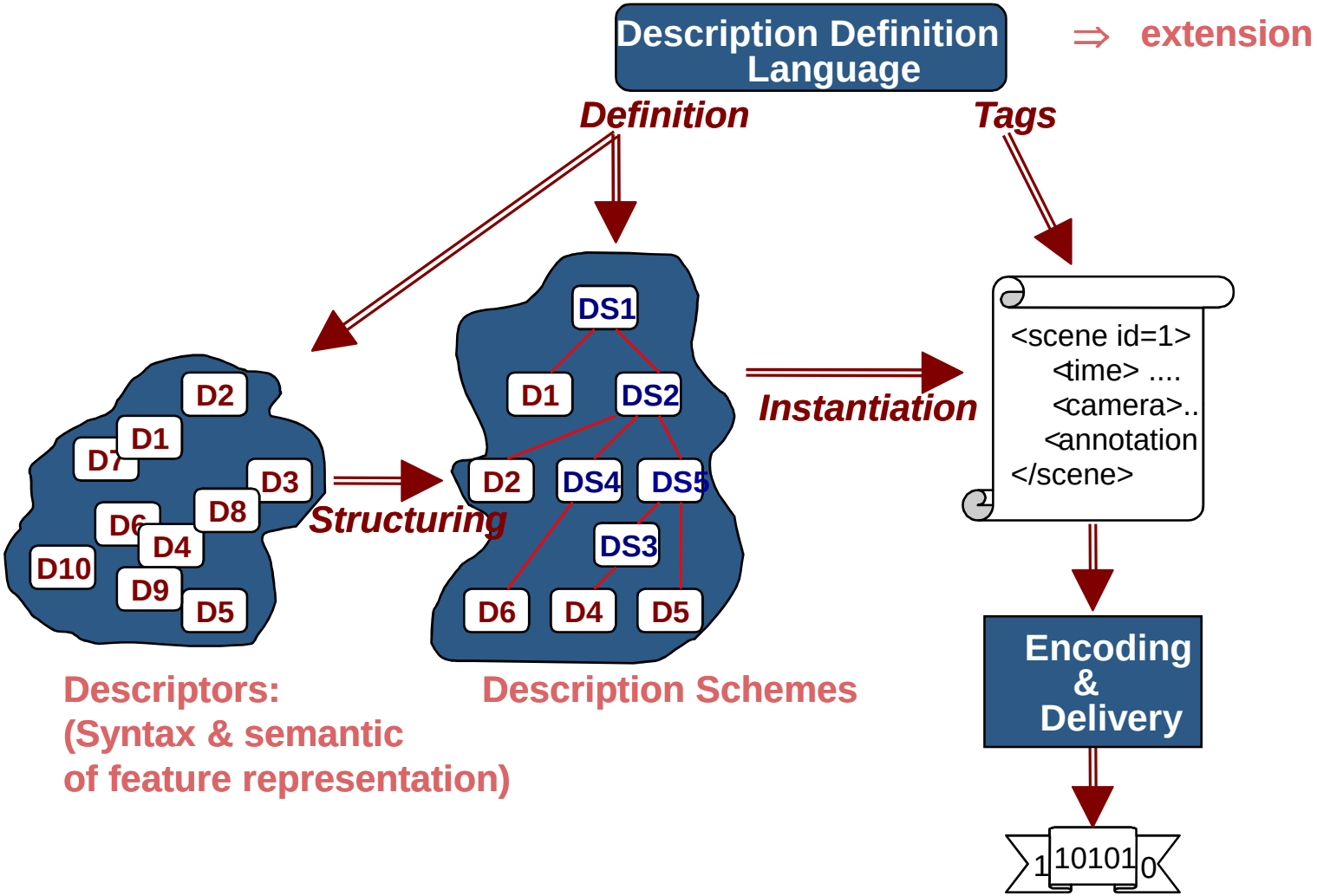
User & computational systems

The content and its description may also be multiplexed

MPEG-7 elements

- **Descriptors (D):**
  - to represent Features. Descriptors define the syntax and the semantics of each feature representation.
- **Description Schemes (DS):**
  - to specify the structure and semantics of the relationships between their components, which may be both Ds and DSs.
- **Description Definition Language (DDL):**
  - to allow the creation of new DSs and, possibly, Ds and to allows the extension and modification of existing DSs.
- **System tools:**
  - to support multiplexing of descriptions, synchronization of descriptions with content, transmission mechanisms, file format, etc.

MPEG-7 working areas



Parts of the MPEG-7 Standard

- Part 1: Systems
- Part 2: Description Definition Language
- Part 3: Visual
- Part 4: Audio
- Part 5: Multimedia Description Schemes
- Part 6: Reference Software
- Part 7: Conformance testing
- Part 8: Extraction and use of MPEG-7 descriptions (TR)
- Part 9: Profiles and levels
- Part 10: Schema definition
- Part 11: MPEG-7 profile schemas
- Part 12: Query format

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System tools

System tools:

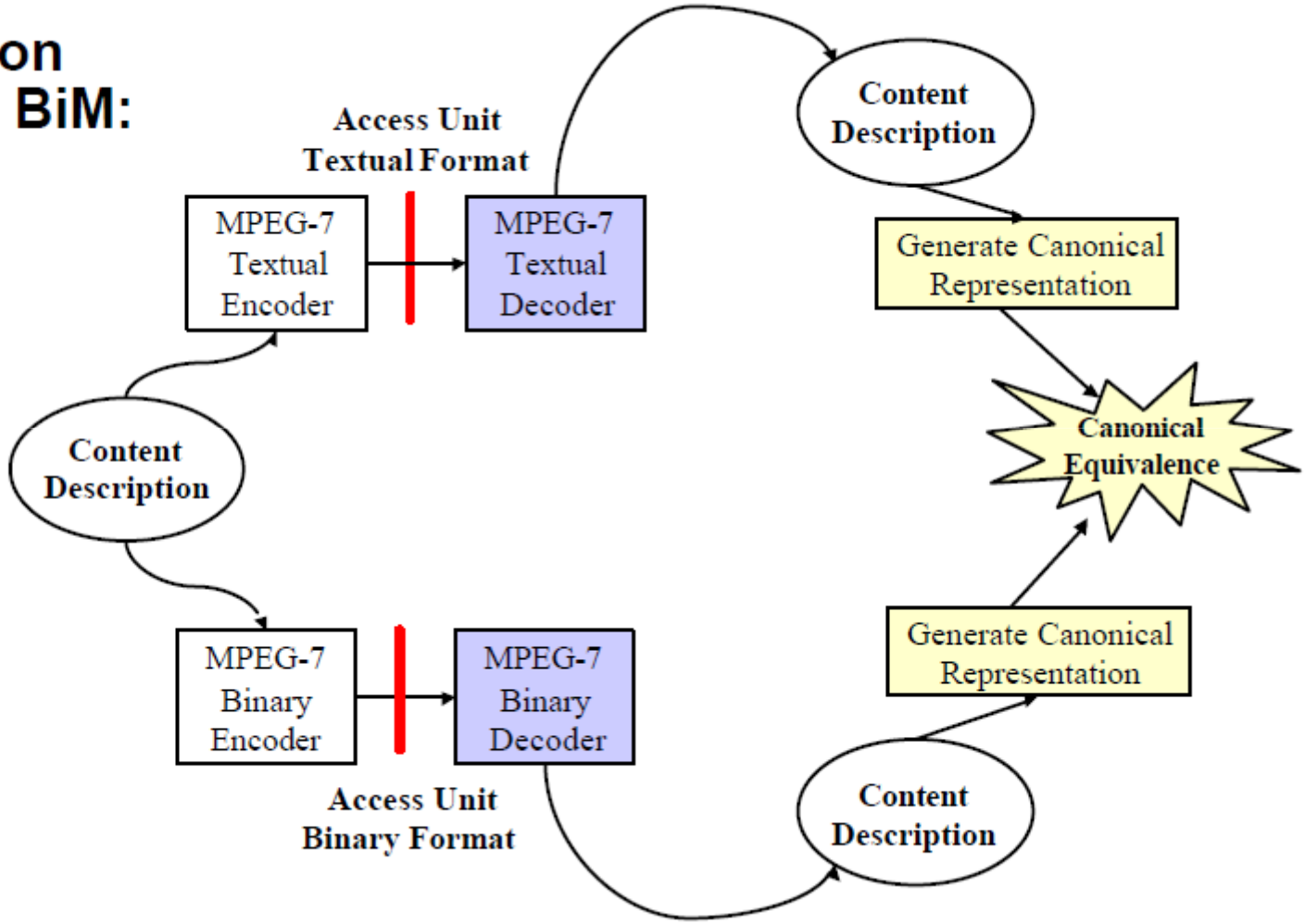
- Two formats:
  - Textual: XML
  - Binary: Binary format for MPEG-7 data (BiM)
- Rationale:
  - XML is human readable, but very verbose
  - Not appropriate for bandwidth efficient storage or transmission
  - BiM allows bandwidth efficient binary representation, dynamic update and flexible streaming
  - High compression ratio
  - MPEG-7 XML file and corresponding BiM stream result in identical descriptions

System tools

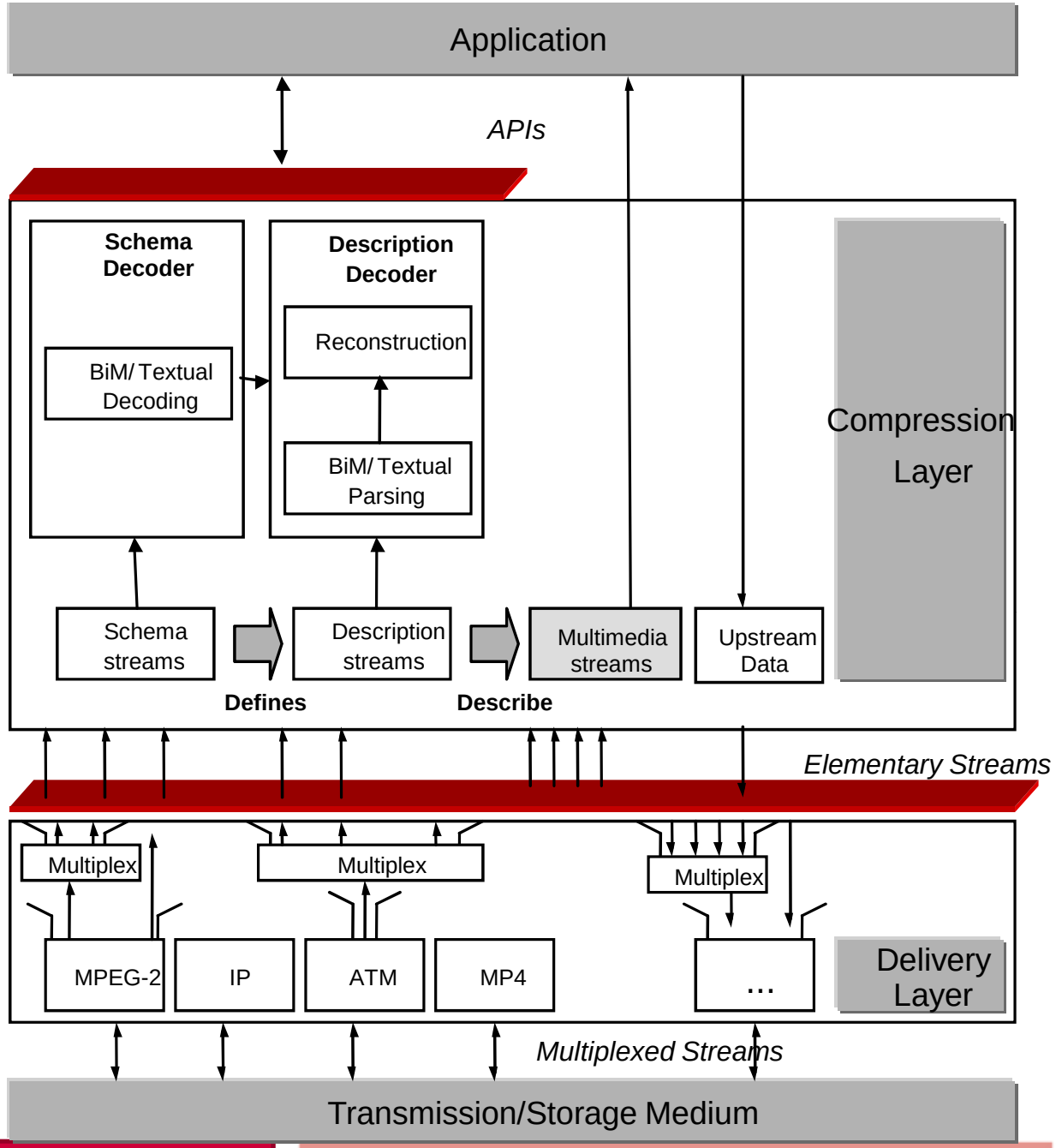
- **System tools:**
  - Streaming and delivery:
    - Split the description in pieces
    - Encapsulate the pieces of description in “access units”
    - Transmit the access units
    - Dynamic description

System tools

Relation XML - BiM:

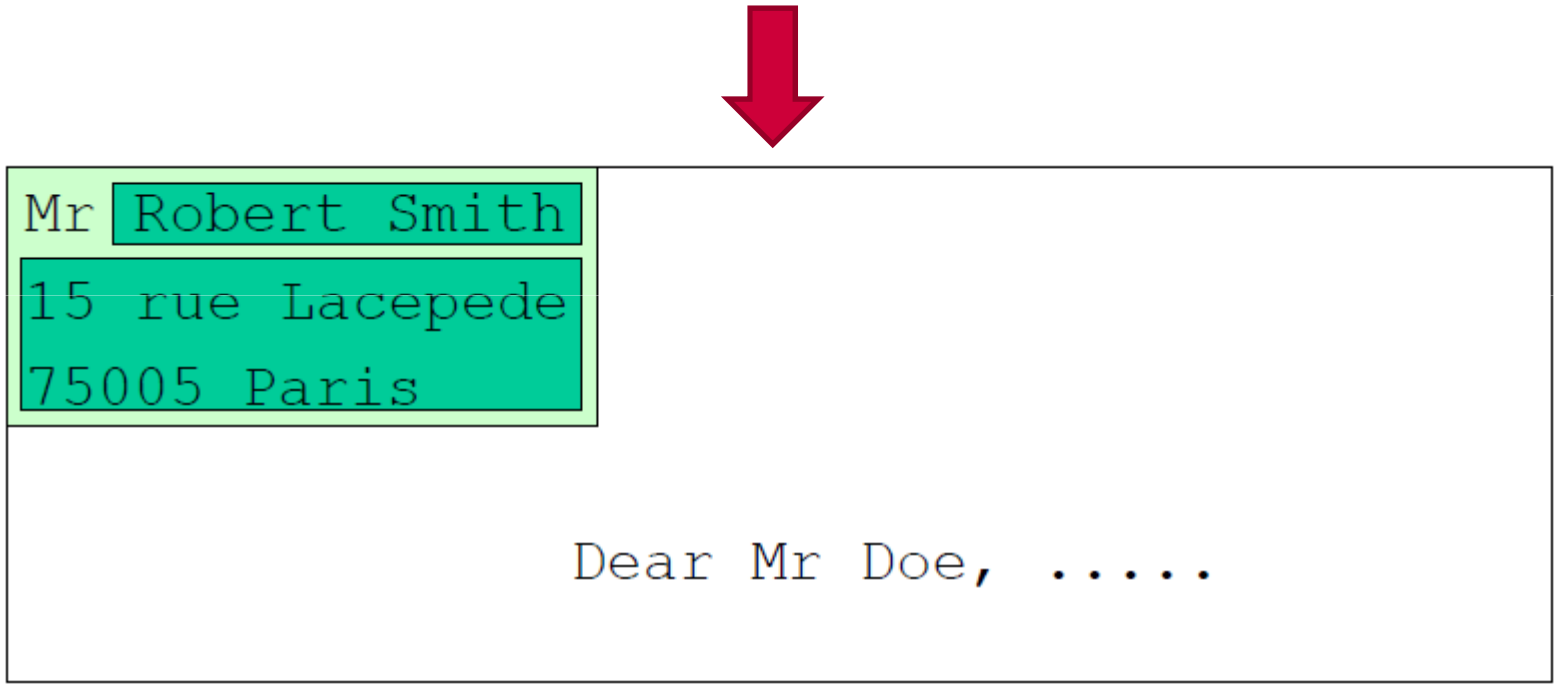


MPEG-7 terminal architecture



Structured document

MrRobertSmith15rueLacepede75005ParisDear MrDoe,.....



Structure is important!

XML

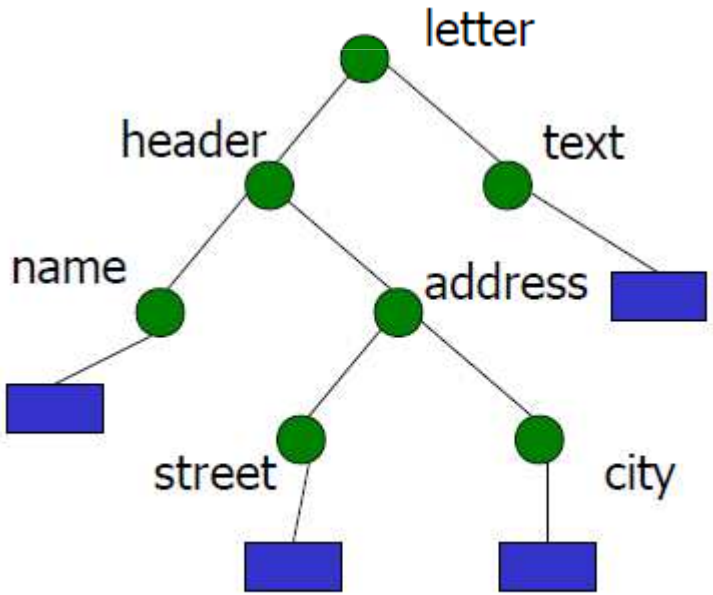
```
<letter>
     <header>
         <name>Mr Robert Smith</name>
         <address>
             <street>15 rue Lacepede</street>
             <city>Paris</city>
         </address>
     </header>

     <text>Dear Mr Doe, ..... </text>
</letter>
```

XML

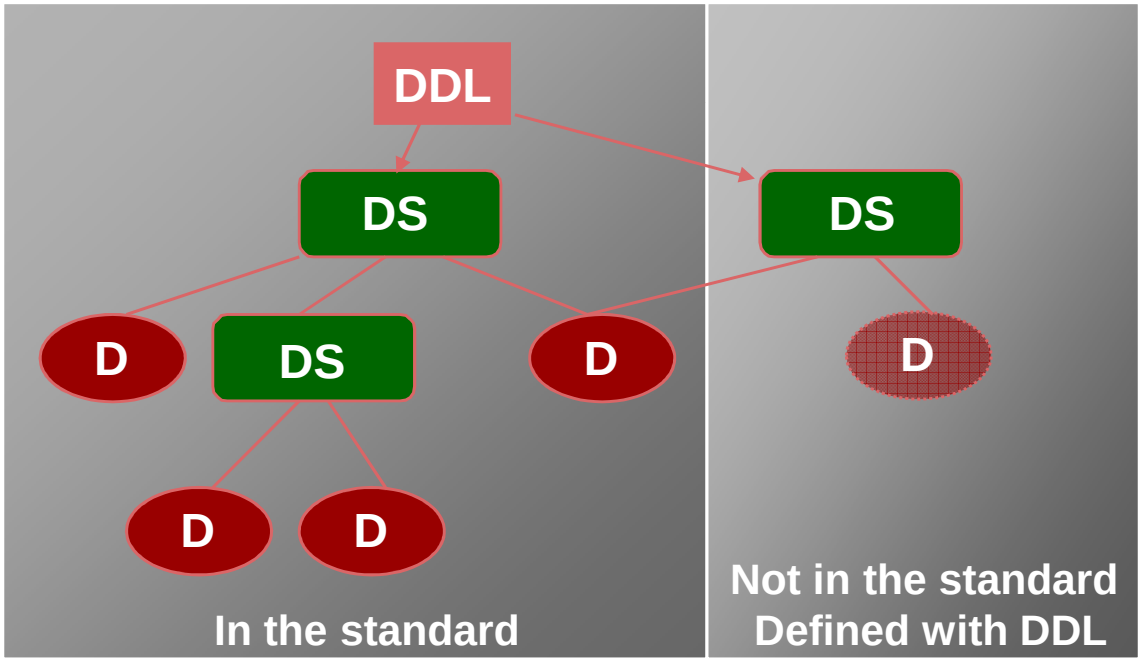
```
<letter>
      <header>
          <name>Mr Robert Smith</name>
          <address>
              <street>15 rue Lacepede</street>
              <city>Paris</city>
          </address>
      </header>

      <text>Dear Mr Doe, ..... </text>
</letter>
```



Description Definition Language

- **Definition of the Ds and DSs:**
  - XML Schema + MPEG-7 extensions
- **Instantiation (description):**
  - XML
- **Allow to define new entities**



DDL: Schema definition

- **DDL**
  - XML-oriented, extends XML Schema (W3C)
  - define MPEG-7 data models
  - can be used to extend MPEG-7 if needed
- **XML Schema:**
  - Datatypes, Simple and Complex types
  - Elements, Inheritance, Abstract types
- **MPEG-7 extensions: do not break an XML Schema parser**
  - Array and Matrix datatype
  - Enumerated datatypes for MimeType, CountryCode, RegionCode, CurrencyCode and CharacterSetCode
  - Typed references

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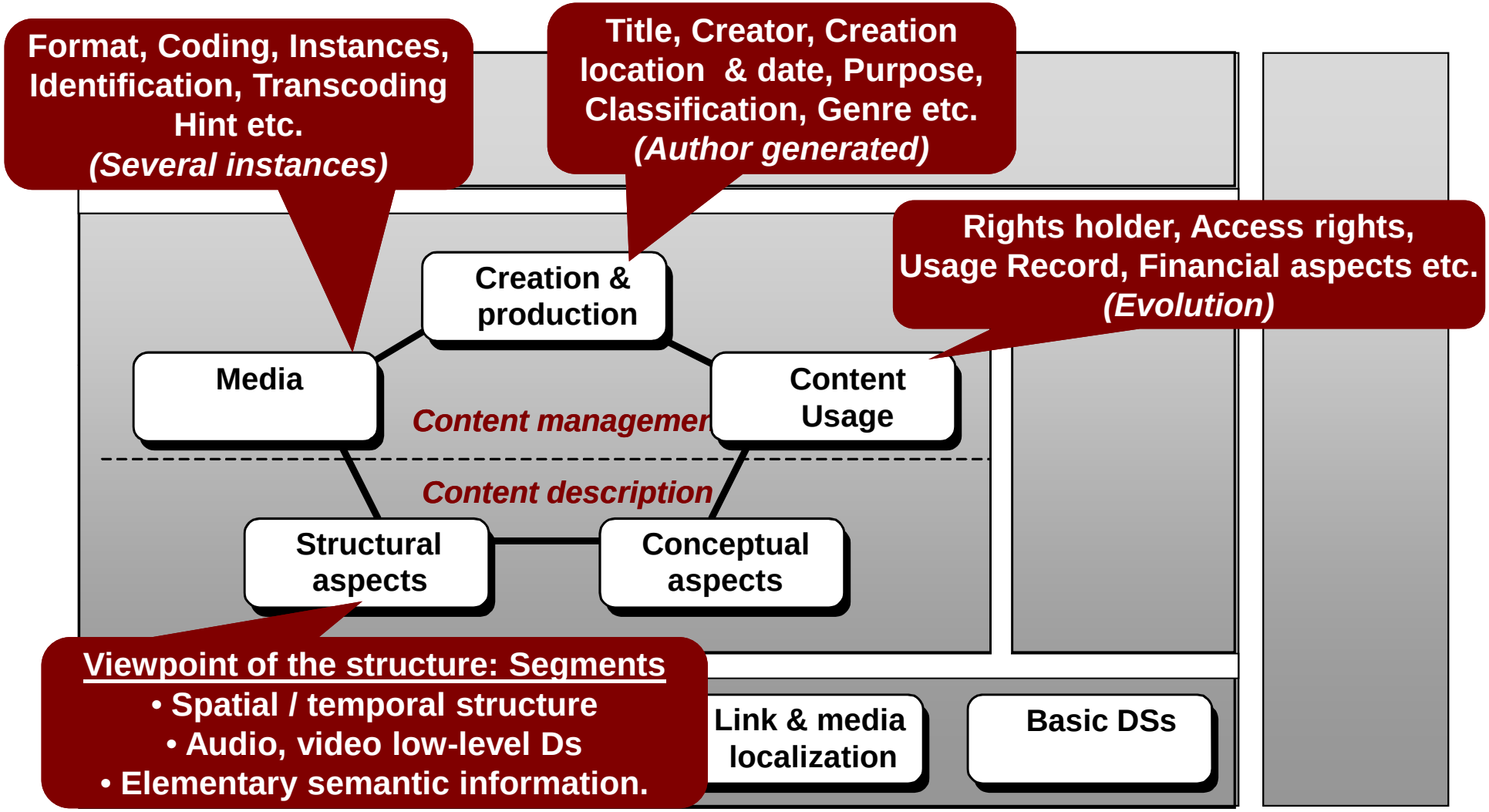
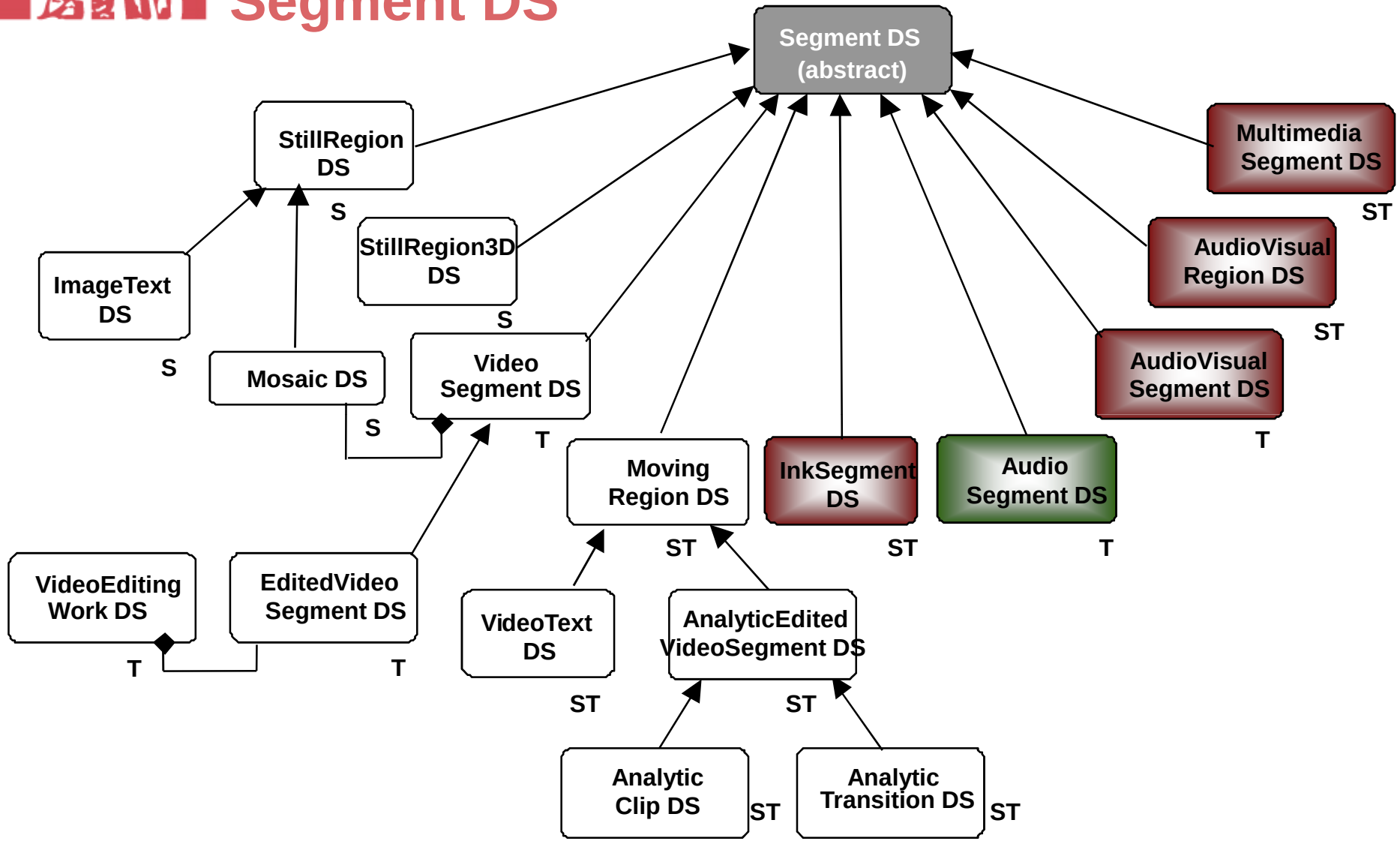
Content Management & Description

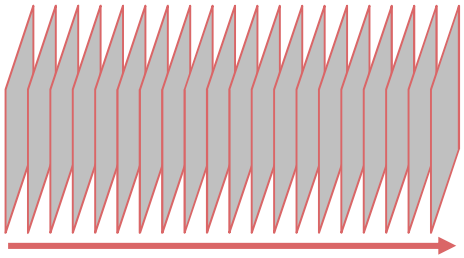


Segment DS

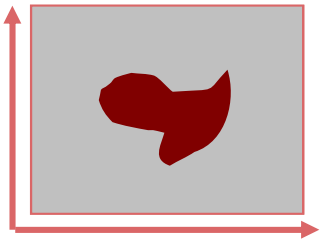

Segment DS (abstract)
StillRegion DS
S
StillRegion3D DS
S
ImageText DS
S
Mosaic DS
S
Video Segment DS
T
Multimedia Segment DS
ST
AudioVisual Region DS
ST
AudioVisual Segment DS
T
Moving Region DS
ST
InkSegment DS
ST
Audio Segment DS
T
VideoEditing Work DS
T
EditedVideo Segment DS
T
VideoText DS
ST
AnalyticEdited VideoSegment DS
ST
Analytic Clip DS
ST
Analytic Transition DS
ST

Examples of Segments

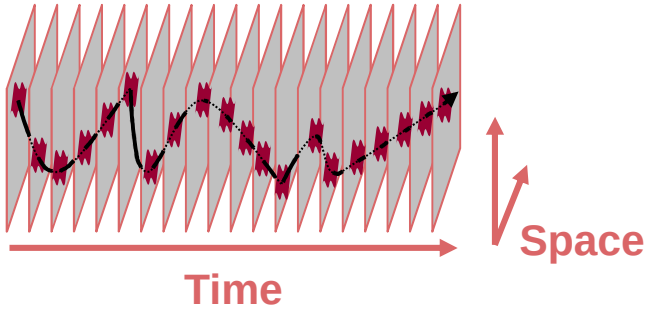
Video segments



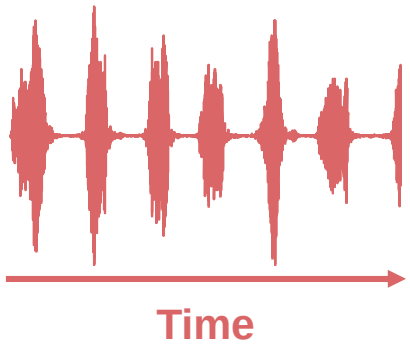
Still regions



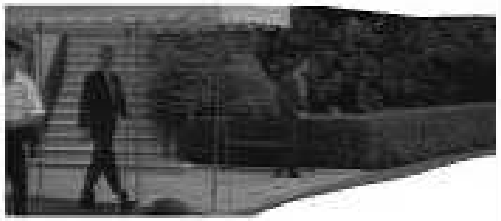
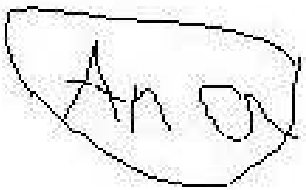
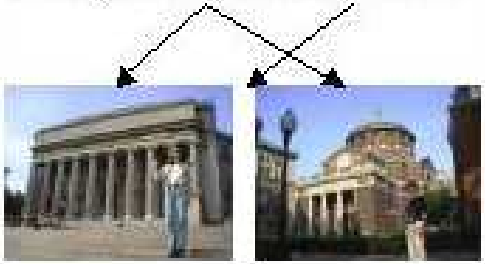
Moving regions



Audio segments

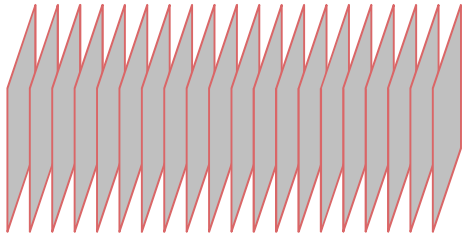


Examples of Segments

Mosaic 	*3D still region* 	*Image text* 
Ink segment 	*Multimedia segment* 	*Analytic clips/transitions* 

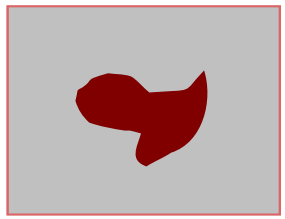
Specific description of segments

Video segments



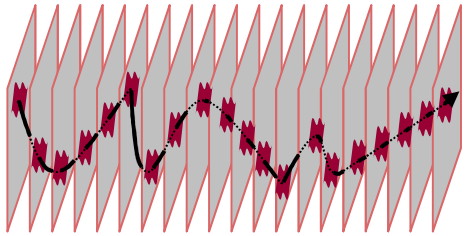
- Color
- Camera motion
- Motion activity
- Mosaic

Still regions



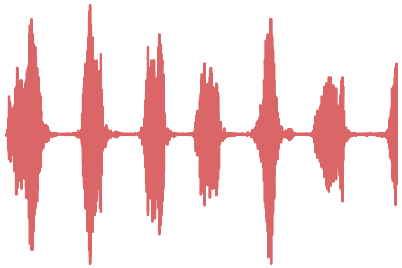
- Color
- Shape
- Position
- Texture

Moving regions



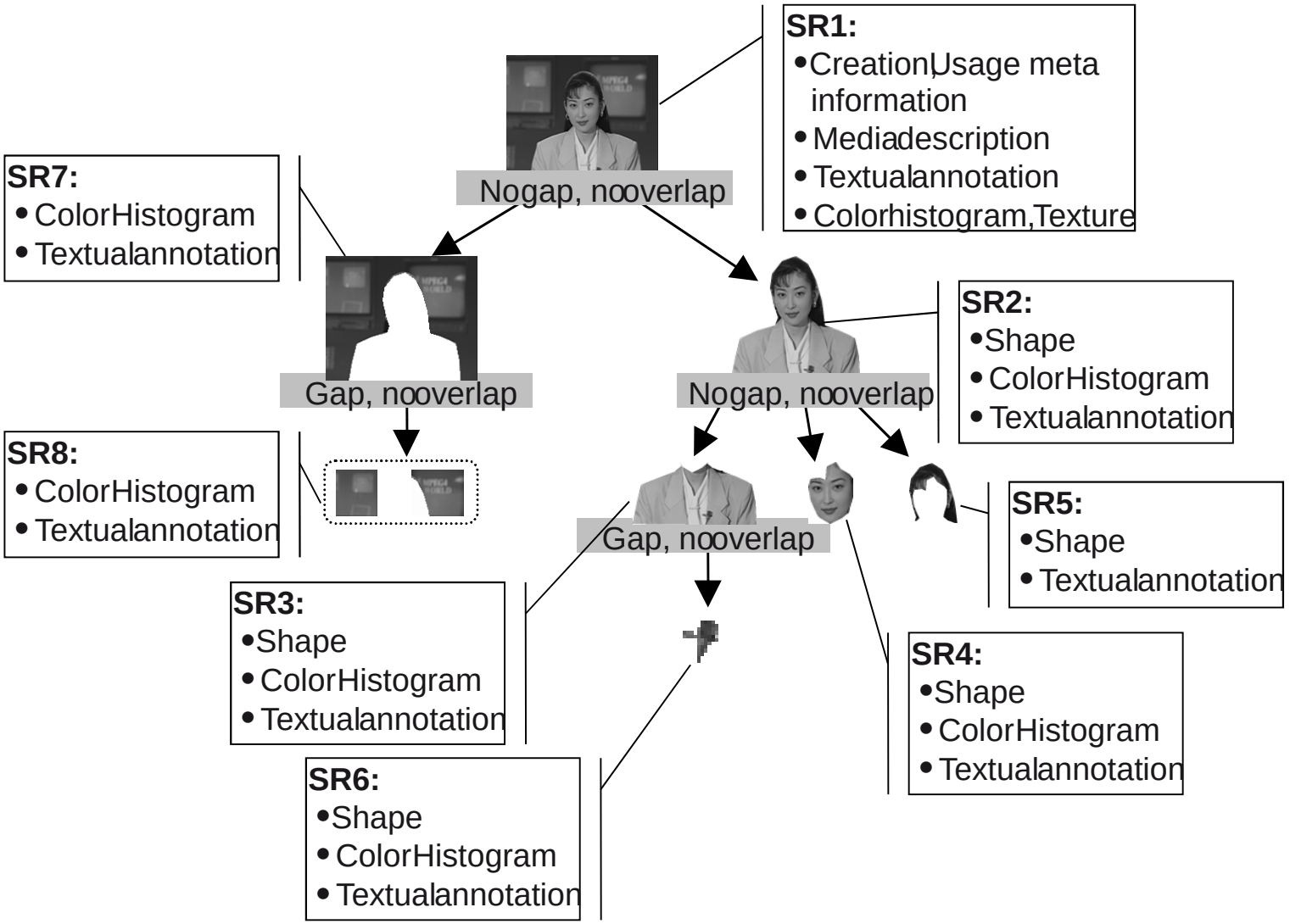
- Color
- Motion trajectory
- Parametric motion
- Spatio-temporal shape

Audio segments



- Spoken content
- Spectral characterization
- Music: timbre, melody

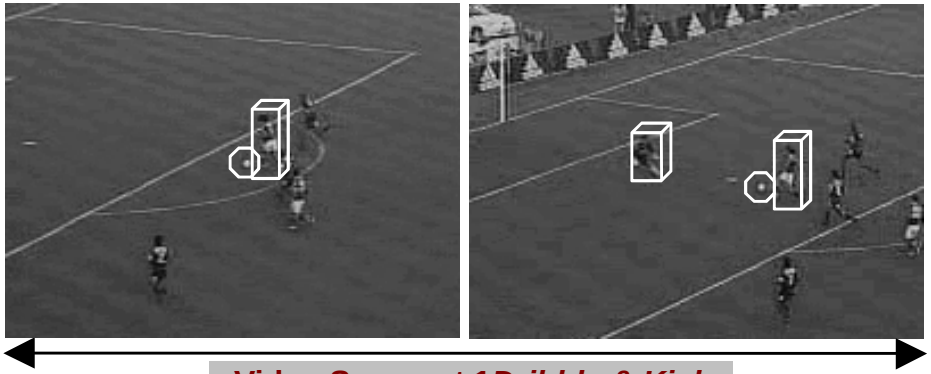
Example of Segment trees



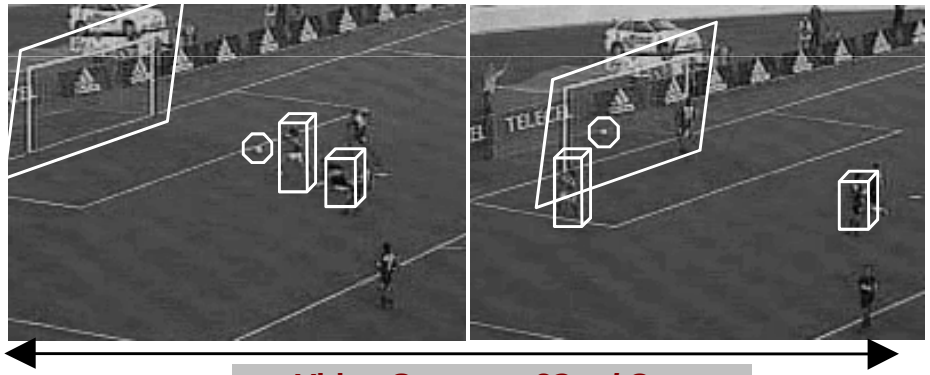
Graph

- **Goal:**
  - The segment DS allows the construction of tree structures
    - Efficient for access, retrieval, compression.
    - Lack of flexibility
  - Graph structure to improve flexibility

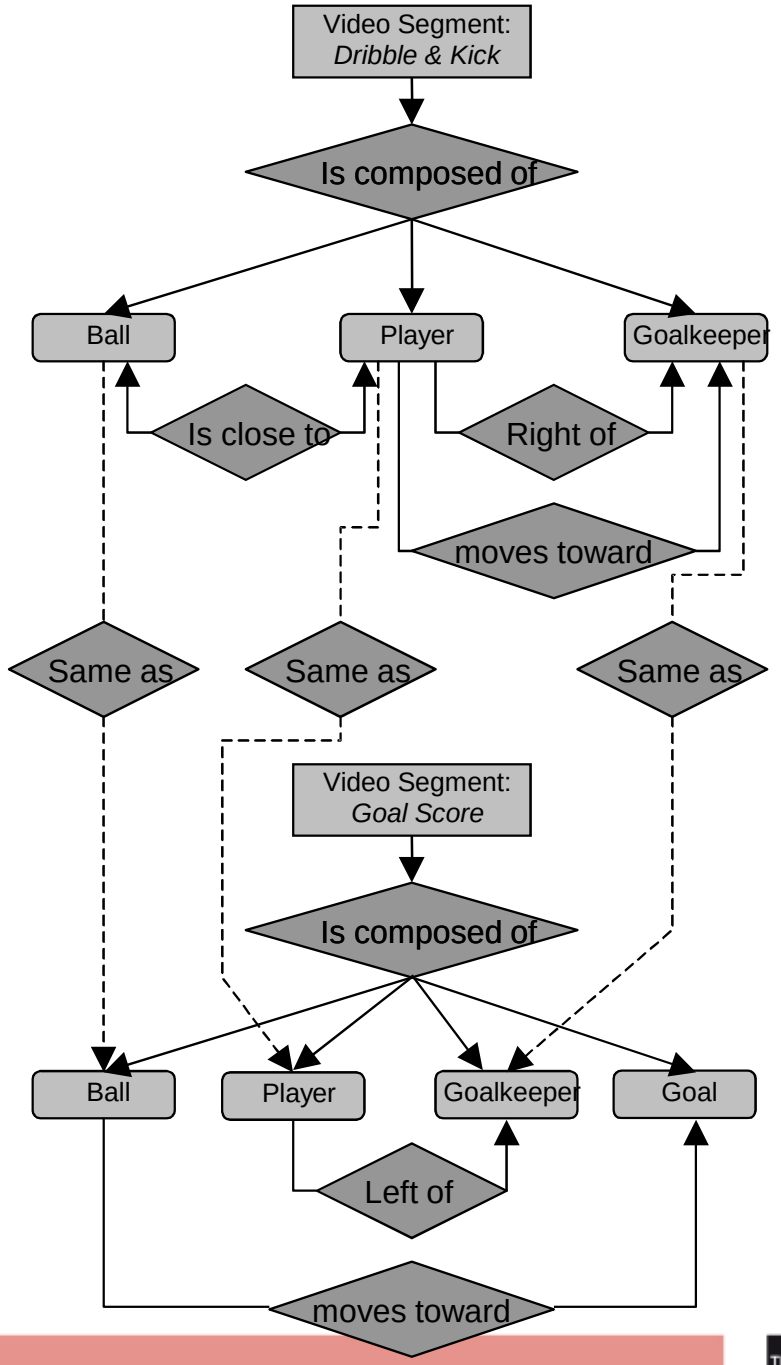
- **Outline of the approach:**
  - Definition of entity nodes representing segments
  - Definition of relationships: space, time, visual



Video Segment 1 *Dribble & Kick*



Video Segment 2 *Goal Score*



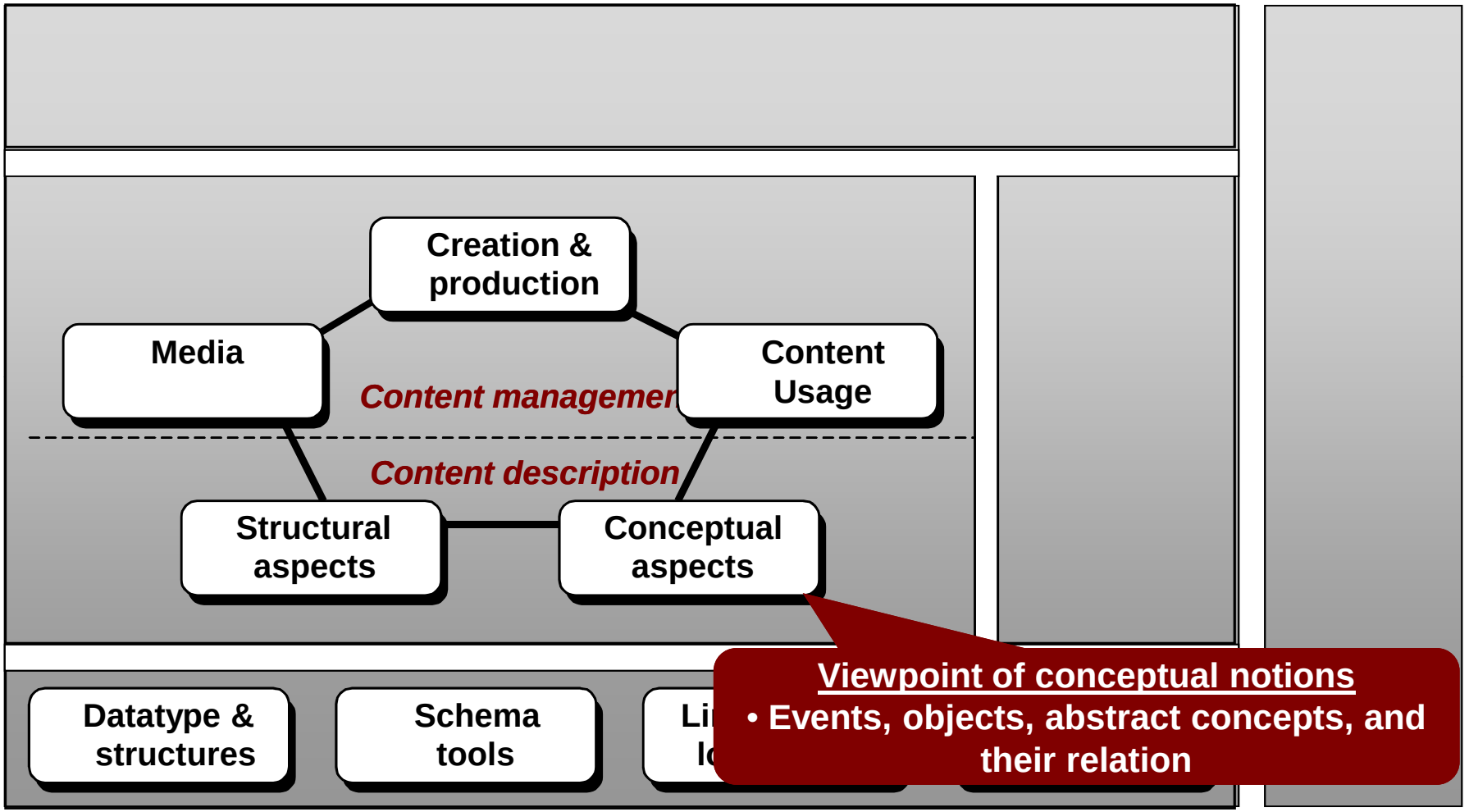
Moving Region: Player

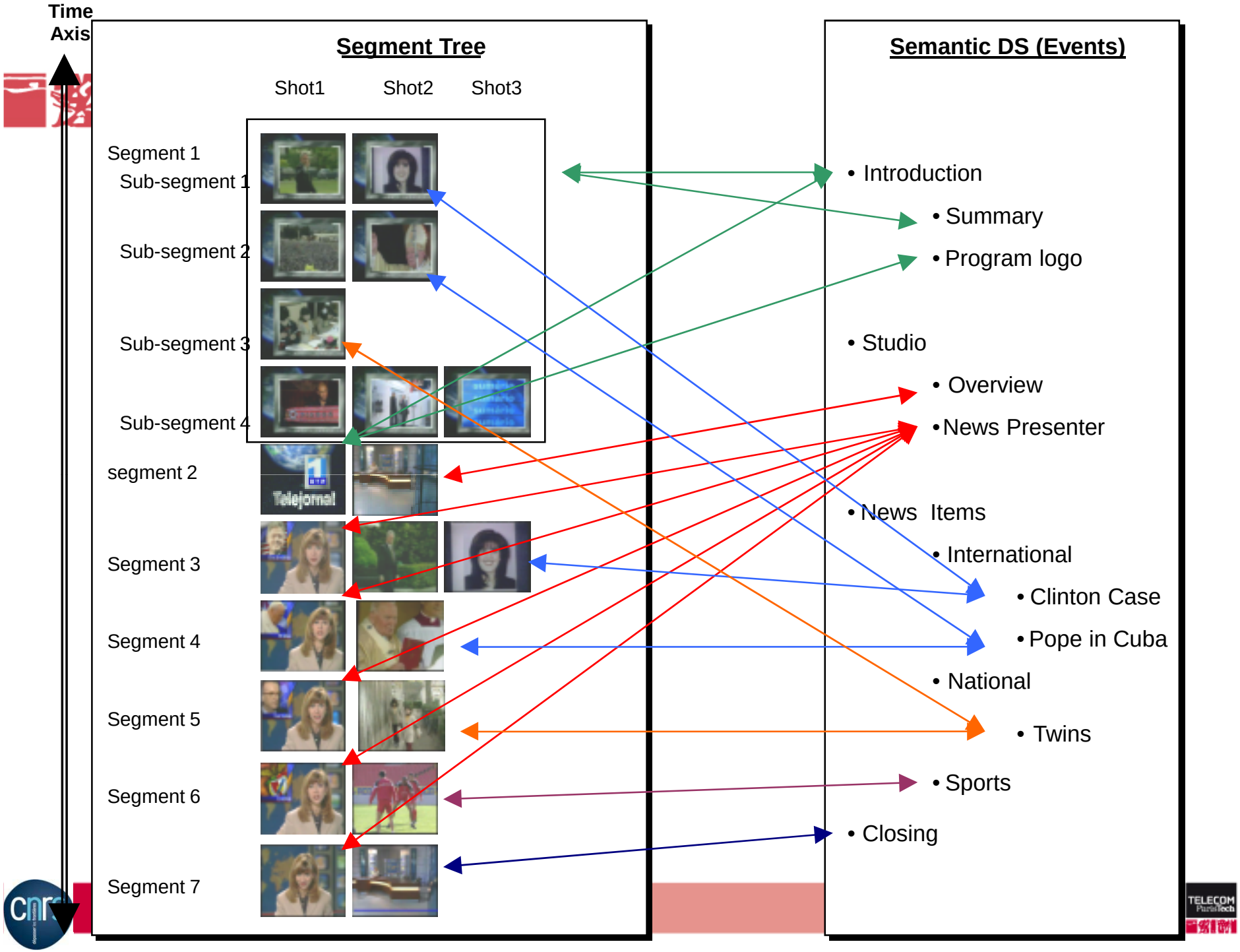
Moving Region: Ball

Moving Region: Goal Keeper

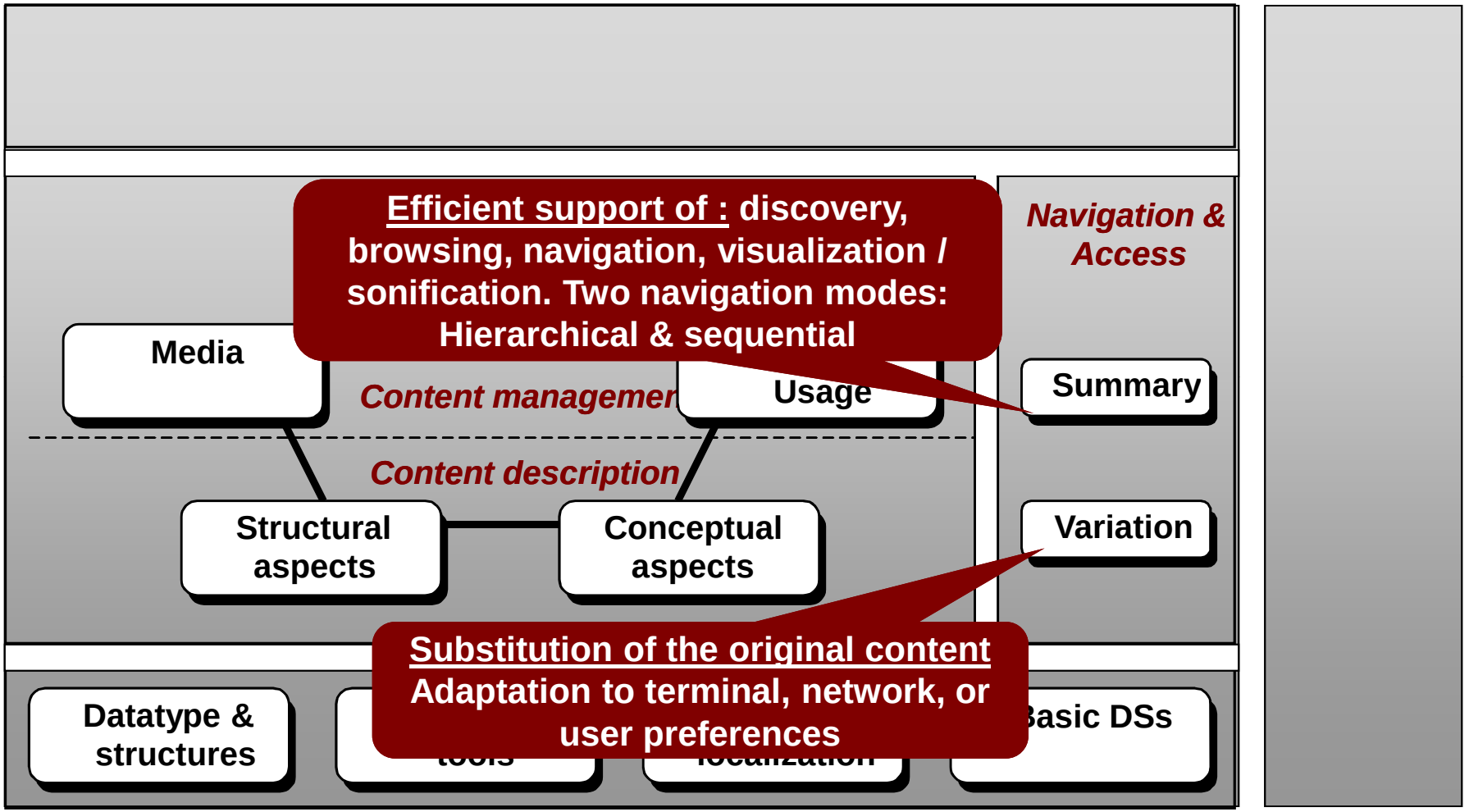
Still Region: Goal

Content Management & Description



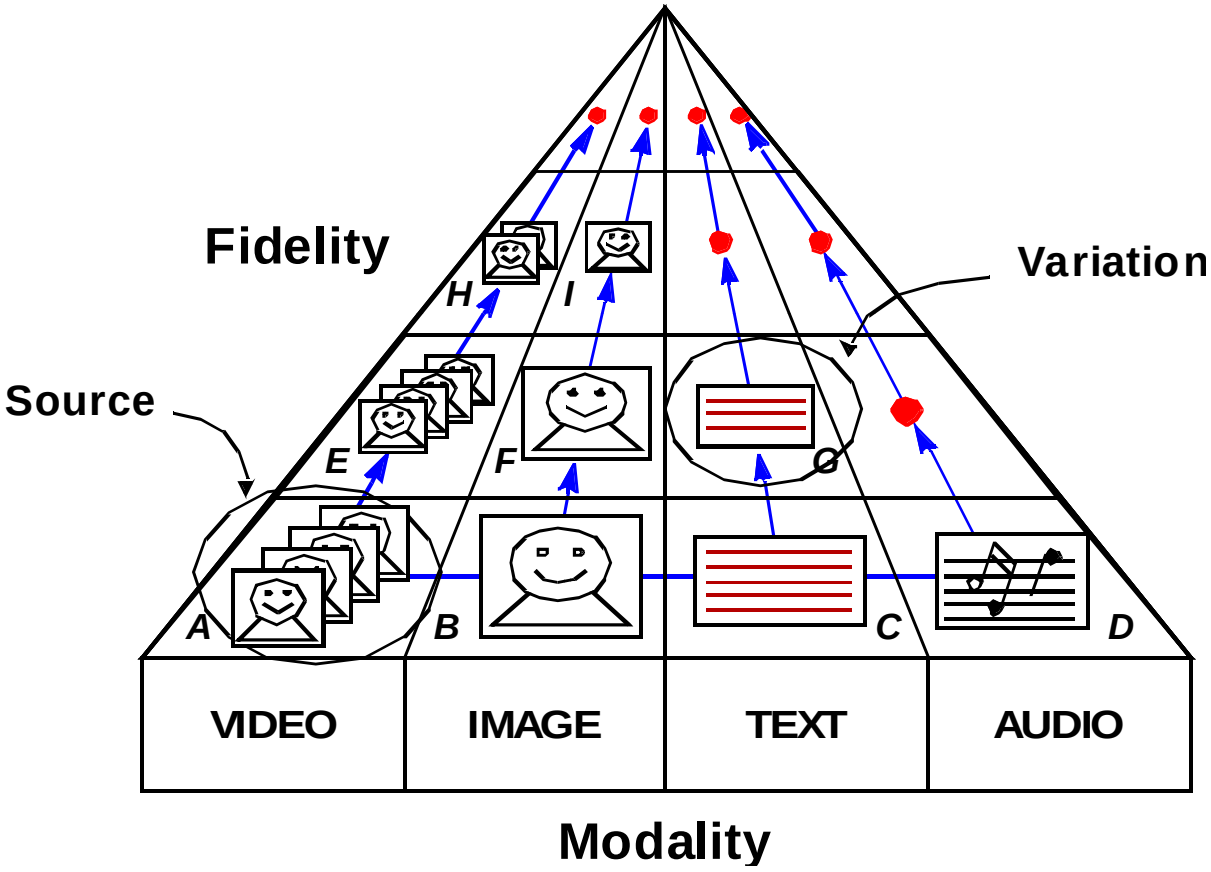

Time Axis
Segment Tree
Shot1
Shot2
Shot3
Segment 1
Sub-segment 1
Sub-segment 2
Sub-segment 3
Sub-segment 4
segment 2
Segment 3
Segment 4
Segment 5
Segment 6
Segment 7
Semantic DS (Events)
• Introduction
• Summary
• Program logo
• Studio
• Overview
• News Presenter
• News Items
• International
• Clinton Case
• Pope in Cuba
• National
• Twins
• Sports
• Closing

Navigation and Access

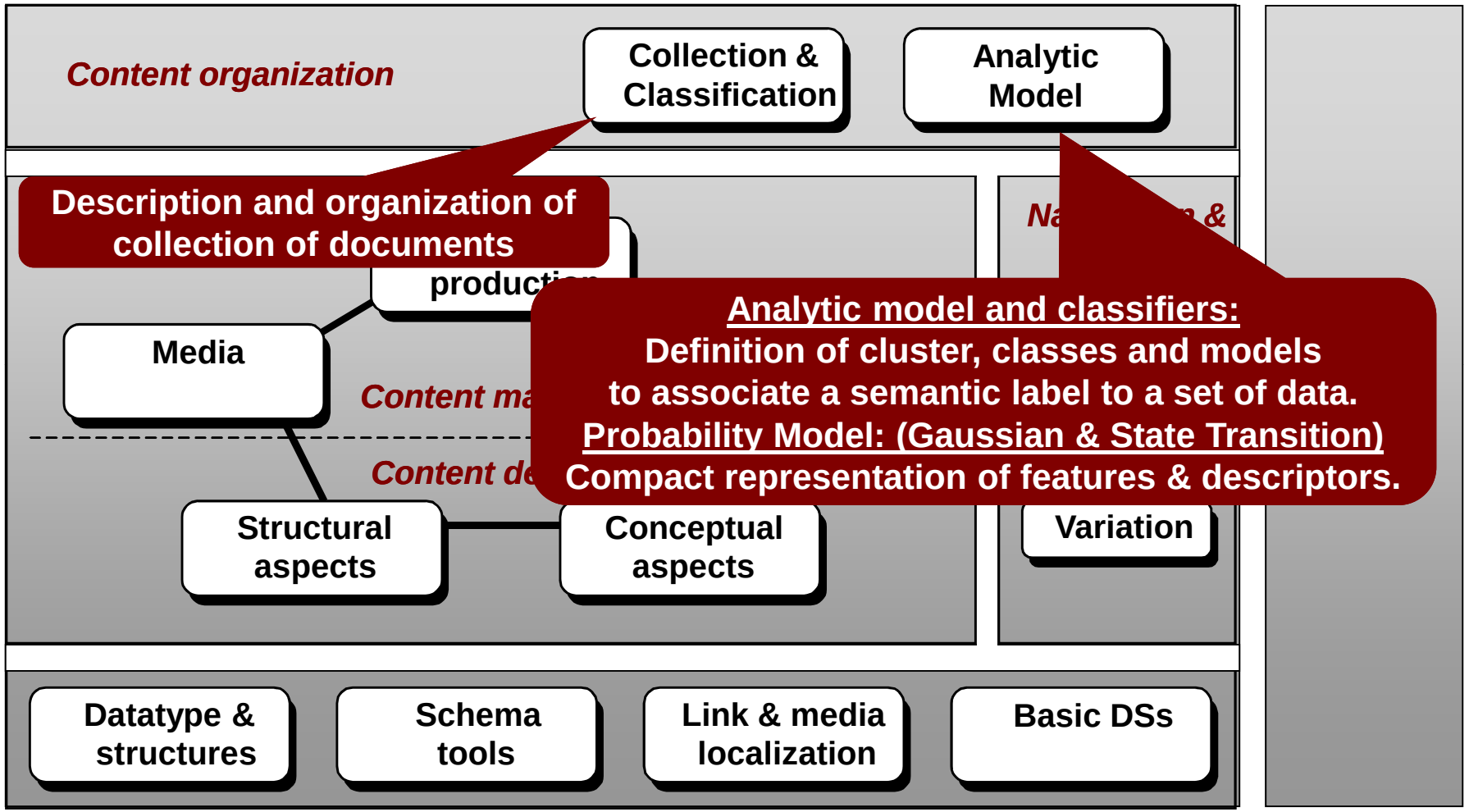


Variation

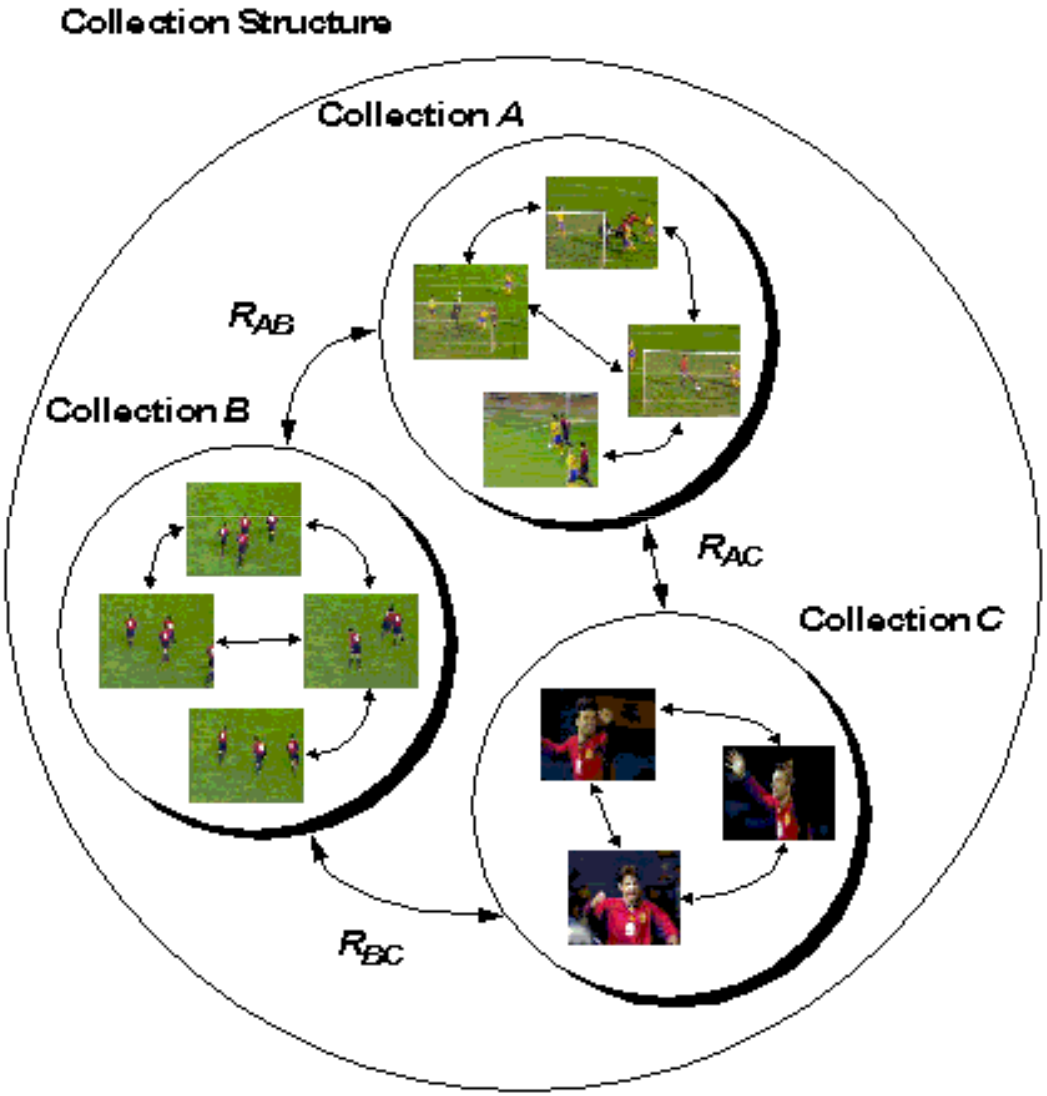
Universal Multimedia Access: Adapt delivery to network and terminal characteristics (QoS)



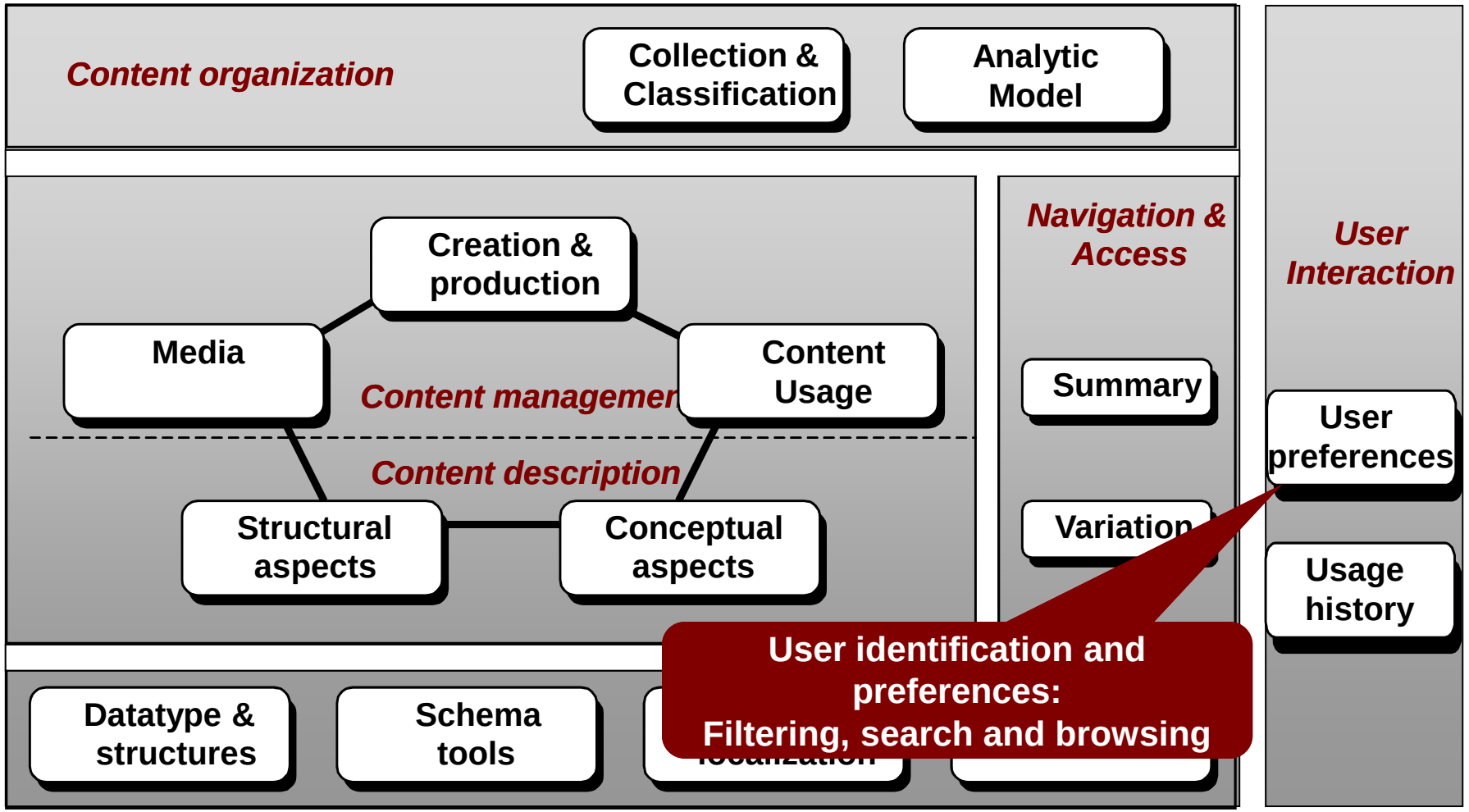
Content Organization



Collection


Collection Structure
Collection A
R_{AB}
Collection B
R_{AC}
Collection C
R_{BC}

User Interaction



Outline

- Objective, goals, requirements and applications
- Basic component of the MPEG-7 standard
- Systems tools and Description Definition Language
- Multimedia Description Schemes
- Visual Tools
- Audio Tools
- Relation with other standards

MPEG-7 Visual Part

MPEG-7 Visual part contains 25 Ds/DSs

Basic Elements (2)

Localization (2)

Containers (3)

Color (7)

Texture (3)

Shape (3)

Motion (4)

Face (1)

Color (1)

- **Dominant Color(s):** *DominantColor*
  - 1-8 dominant colors in image / region
  - color space, quantization, dominant color(s) value(s)
  - variance of color value, percentage of pixels of this color, spatial coherency of color repartition

- **Color Content (histogram):** *ScalableColor*
  - Color histogram in HSV color space, encoded by Haar transform
    - scalable in number of coefficients kept for representation
    - scalable in number of bits per coefficients
    - lower end: 60 bits, very fast matching

Color (2)

- **Color content + coherence of repartition:** *ColorStructure*
  - Histogram of structuring elements that contain a particular color
    - ⇨ Enhanced retrieval (in conjunction with HMMD)

- **Color content + its layout:** *ColorLayout*
  - Based on the DCT coefficients. (size: about 160 bits)
    - ⇨ Layout sensitive retrieval, sketch-to-image matching

- **Color content of Group of Pictures / Frames:** *GoFGoPColor*
  - Aggregation of color histograms (average, median, etc)
    - ⇨ Clustering of data for browsing / retrieval

Texture (1)

- **Characterization of homogeneous textures:**
  - Low-level: *HomogeneousTexture* ⇨ retrieval
  - High-level: *TextureBrowsing* ⇨ browsing

- **Characterization of structures in generic images:**
  - edges content and layout: *EdgeHistogram*

Texture (2)

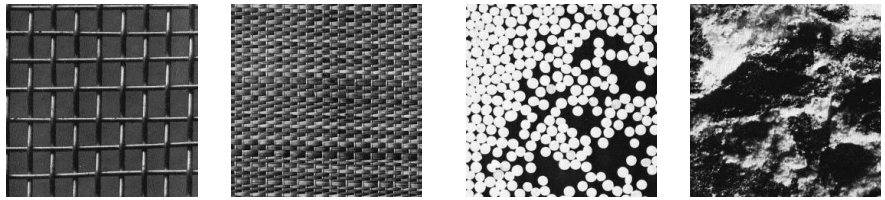
HomogeneousTexture

In the frequency domain:

- Decomposition into 30 channels (5 scales, 6 angles) using Gabor filters
- Energy and energy deviation

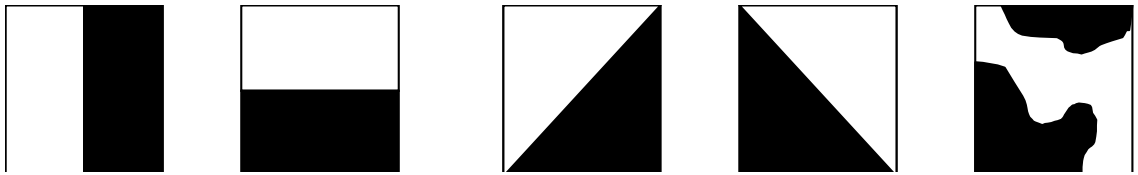
TextureBrowsing

- Main direction(s)
- Regularity (1 to 4)
- Coarseness (1 to 4)



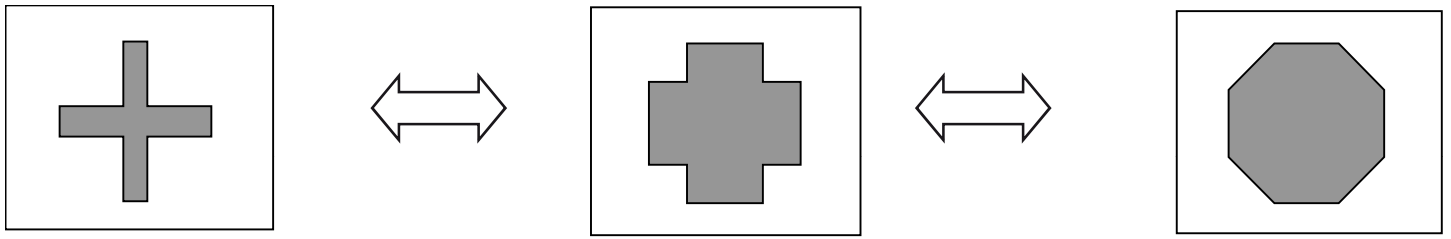
EdgeHistogram

- Fixed size: 240 bits
- Edge types histograms on 16 sub-images



Shape (1)

- **2D:** *ContourShape* **and** *RegionShape*



- **3D:** *Shape3D*

Shape (2)

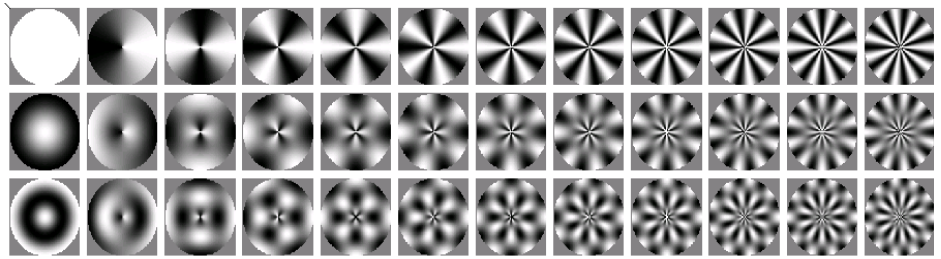
Contour Based: *ContourShape*

Curvature Scale Space:

- curvature points importance and relative positions
- Variable size: < 15 Bytes

Region Based: *RegionShape*

- Angular Radial Transf. (ART) moments

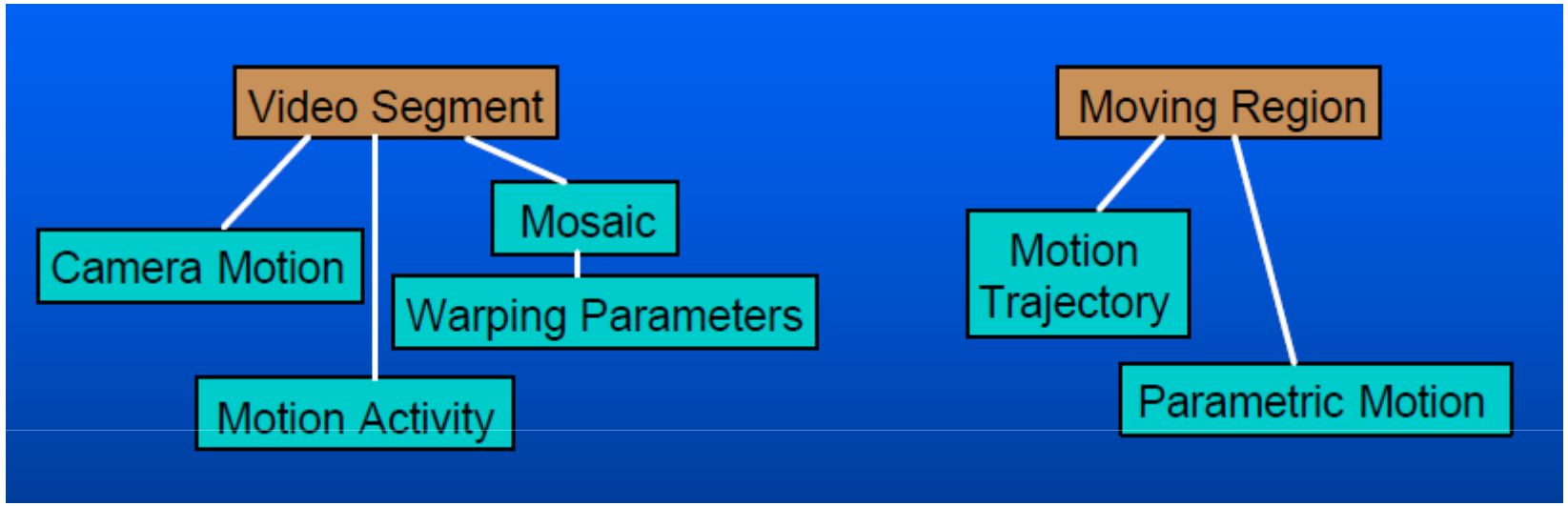


- Fixed size: 17.5 Bytes

Shape3D

- Based on 3D meshes
- Histogram of 3D shape indexes (Koenderink) representing local curvature properties of the 3D surface

Motion (1)



MotionActivity

browsing, repurposing

CameraMotion

browsing, high level queries

MotionTrajectory

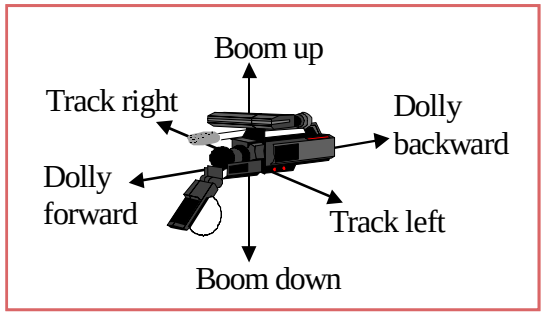
retrieval, high level queries

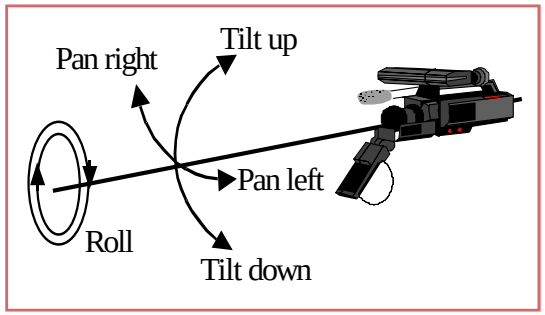
ParametricMotion

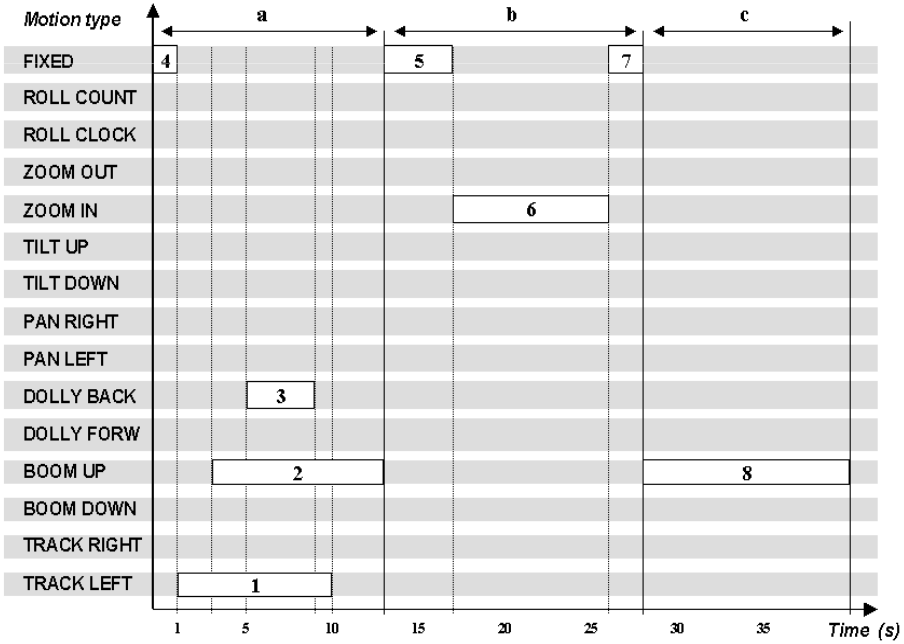
mosaic, retrieval

Motion (2)

- **Motion Activity:** *MotionActivity*
  - Intensity of motion (1 to 5)
  - main direction(s)
  - spatial and temporal distribution
- **Camera Motion:** *CameraMotion*

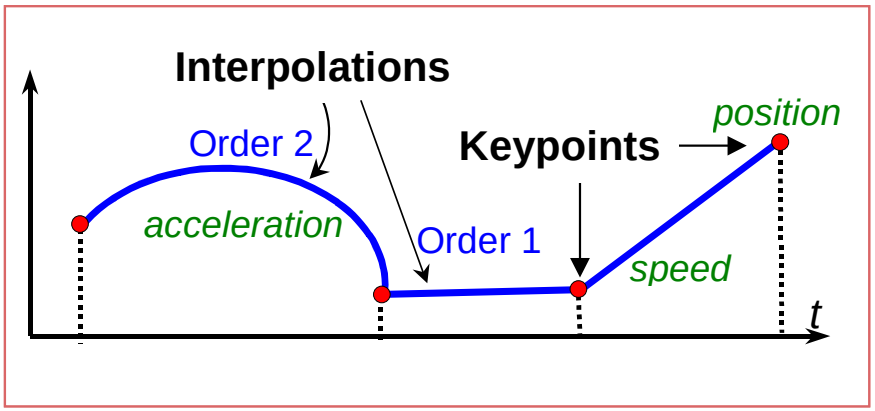






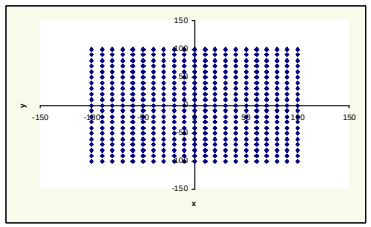
Motion (3)

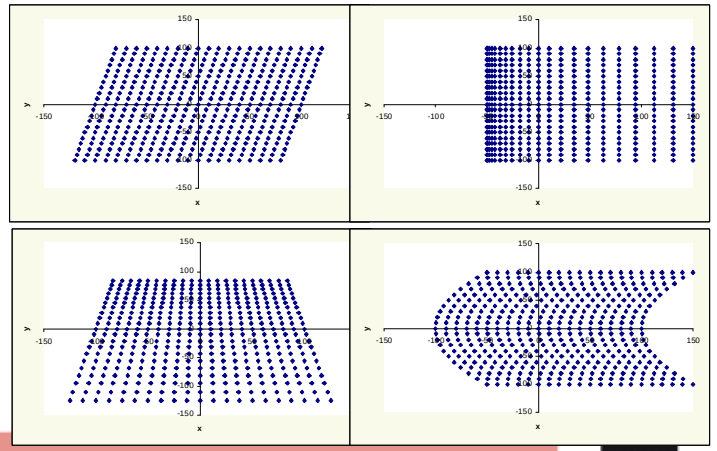
- **Motion Trajectory:** *MotionTrajectory*



Queries:
- **similarity**
- **high level**

- **Parametric Motion:** *ParametricMotion*
  - translational
  - rotation/scaling
  - affine
  - planar perspective
  - parabolic





Face

- **Face Characterization:** *FaceRecognition*
  - Size: 238 bits
  - Based on eigenfaces (vector of 56*46 values, extracted from normalized faces)
    - 49 basis vectors which span the space of possible face vectors
    - projection of the face vector on the 49 eigenfaces

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Audio descriptors

- **Low level audio features:**
  - Waveform and spectrum envelops
  - Power, spectrum centroid, spectrum spread
  - Fundamental frequency, harmonicity
  - Independent spectral component representation
- **Spoken content**
  - Lattice of hypothesis
- **Music:**
  - Timbre, Melody
  - Genre
- **Silence description**

Use of description tools

- Library of tools!
- The description tools are presented on the basis of the functionality they provide.
- In practice, they are combined into meaningful sets of description units.
- Furthermore, each application will have to select a sub-set of descriptors and DSs.
- DDL can be used to handle specific needs of the application.

MPEG-7 XML image description

Unstructured news image

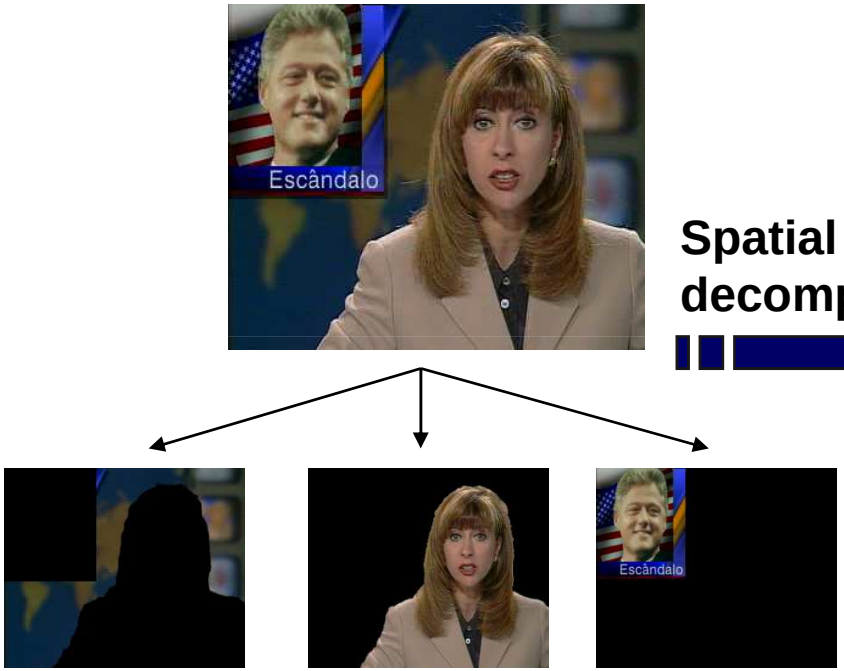
MPEG-7 XML image description

Title

<StillRegion id = “news”>

</StillRegion>

MPEG-7 XML image description



Spatial decomposition

```
<StillRegion id = “news”>
  <SegmentDecomposition
   decompositionType = “spatial”>
    <StillRegion id = “background”>
    <StillRegion id = “speaker”>
    <StillRegion id = “topic”>
  </SegmentDecomposition>
</StillRegion>
```

MPEG-7 XML image description

Background feature

```
<StillRegion id = “news”>
  <SegmentDecomposition
    decompositionType = “spatial”>
    <StillRegion id = “background”>
      <DominantColor> 10 10 250 </DominantColor>
    <StillRegion id = “speaker”>
    <StillRegion id = “topic”>
  </SegmentDecomposition>
</StillRegion>
```

MPEG-7 XML image description

More features

```
<StillRegion id = “news”>
  <SegmentDecomposition
    decompositionType = “spatial”>
    <StillRegion id = “background”>
    <StillRegion id = “speaker”>
      <TextAnnotation>
        <FreeTextAnnotation> Journalist Judite  Sousa
        </FreeTextAnnotation>
      </TextAnnotation>
      <SpatialMask>
        <Poly>
        <CoordsI> 80 288 100 200 … 352 288 </CoordsI>
        </Poly>
      </SpatialMask>
    <StillRegion id = “topic”>
  </SegmentDecomposition>
</StillRegion>
```

MPEG-7 XML image description

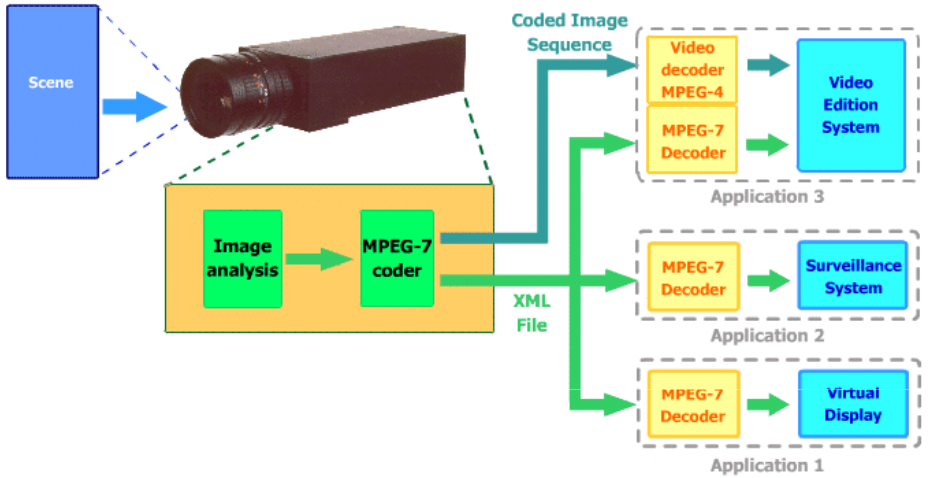

```
<StillRegion id = “news”>
  <SegmentDecomposition  decompositionType = “spatial”>
    <StillRegion id = “background”>
      <DominantColor> 10 10 250 </DominantColor>
    </StillRegion>
    <StillRegion id = “speaker”>
      <TextAnnotation>
        <FreeTextAnnotation> Journalist Judite Sousa </FreeTextAnnotation>
      </TextAnnotation>
      <SpatialMask>
        <Poly>
        <CoordsI> 5 25 10 20 15 15 10 10 5 15 </CoordsI>
        </Poly>
      </SpatialMask>
    </StillRegion>
    <StillRegion id = “topic”>
      <TextAnnotation>
        <FreeTextAnnotation> Clinton’s affair</FreeTextAnnotation>
      </TextAnnotation>
    </StillRegion>
</SegmentDecomposition>
</StillRegion>
```

MPEG-7 camera

The MPEG-7 camera describes a scene in terms of semantic objects and of their properties

XML scene description

MPEG-7 camera



- Image analysis: segmentation, change detection, and tracking (implemented on the camera DSP).
- MPEG-7 coder: scene description represented using MPEG-7 (XML).
- MPEG-7 decoder: MPEG-7 description is parsed. Extraction of the information related to the specific applications.

MPEG-7 camera

XML scene description

```
<!-- ################################################## --!>
<!-- DDL output for object 4                            --!>
<!-- ################################################## --!>

<Object id="4">

  <RegionLocator>
    <BoxPoly> Poly </BoxPoly>
    <Coords1> 237 222 </Coords1>
    <Coords2> 230 252 </Coords2>
    <Coords3> 240 286 </Coords3>
    <Coords4> 308 287 </Coords4>
    <Coords5> 312 284 </Coords5>
  </RegionLocator>

  <DominantColor>
    <ColorSpace>  YUV  </ColorSpace>
    <ColorValue1> 143.4 </ColorValue1>
    <ColorValue2> 123.3 </ColorValue2>
    <ColorValue3> 128.2 </ColorValue3>
  </DominantColor>

  <HomogeneousTexture>
    <TextureValue> 9.02 </TextureValue>
  </HomogeneousTexture>

  <MotionTrajectory>
    <TemporalInterpolation>
      <KeyFrame>  100  </KeyFrame>
      <KeyPos> 268.6 251.7 </KeyPos>
      <KeyFrame>  101  </KeyFrame>
      <KeyPos> 262.8 241.0 </KeyPos>
                  ...

      <KeyFrame>  138  </KeyFrame>
      <KeyPos> 192.9 79.0 </KeyPos>
    </TemporalInterpolation>
  </MotionTrajectory>

</Object>
```

MPEG-7 camera for video surveillance

- ☺Privacy: in surveillance applications persons feel uncomfortable to be filmed. Only the behavior of the persons are transmitted.
- ☺Checking intentions in surveillance: deduce intentions by studying how a person moves.
- ☺Extract various statistics without revealing identity of people

original frame | segmentation mask | bounding box

Relation with other standards

- SMPTE
  - Material Exchange Format (MXF)
  - Metadata dictionary, KLV encoding
- European Broadcast Union
- Dublin Core Metadata Initiative
- W3C: XML Schema, NewsML etc.
- TV AnyTime Application
- JPEG
  - JPSearch

Conclusions

- **MPEG-7:**
  - AV content description for interoperable applications
- **Description Definition Language:**
  - XML Schema (flexibility) + Binary version (efficiency)
- **Description Schemes and Descriptors:**
  - Library of description tools
  - Covers a wide range of generic needs
  - Structural aspects close to Signal / Image Processing (segment trees and graph).
  - Low-level Descriptors characterize Segments.

Further information

- **Major MPEG-7 documents are public:**
  - MPEG Home page: http://mpeg.chiariglione.org/standards/mpeg-7/mpeg-7.htm
  - Public documents: http://mpeg.chiariglione.org/working_documents.htm
  - Also check:
    - http://www.m4if.org/resources.php#Section40
    - http://en.wikipedia.org/wiki/MPEG-7