8 Multimedia Content Description

Literature:

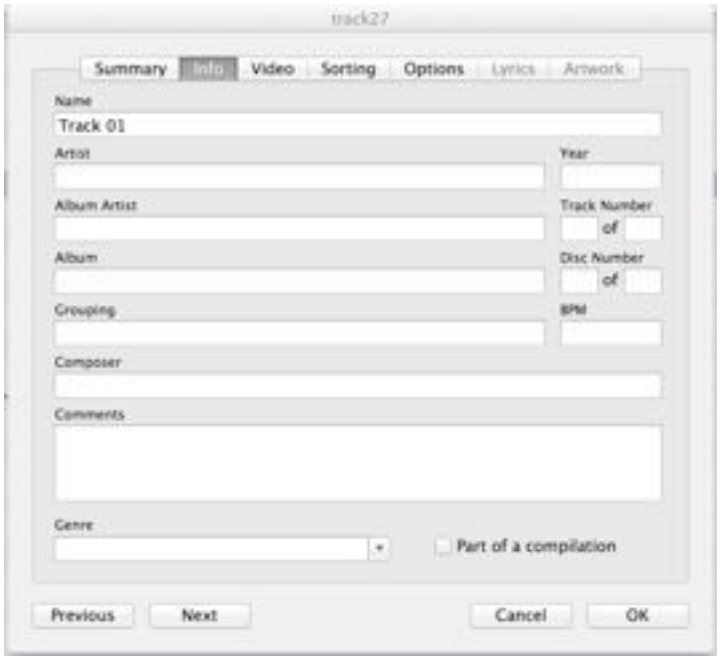
Rosenblatt/Trippe/Mooney, Digital Rights Management, Chapter 6

Troncy/Huet/Schenk, Multimedia Semantics - Metadata, Analysis and Interaction, Wiley 2011

Unlabelled Stuff

- The Unlabeled Video Tape Problem
  - Even worse with digital media: Various formats, variants
- Digital media production:
  - Labeling of parts to be composed
    - » Date, time, format, ...
  - Representing the composition
- Digital media on the Internet
  - Identifying digital media
    - » Title, author, genre, ...
  - Searching for specific media, e.g. audio, video content
  - Fine-grained search within media
    - » e.g. person search within video content
  - Bringing together related media (e.g. text news and photos)
    - » (Automated) syndication

playitagainvideo.com



Content, Essence, Metadata

- Content
  - consists of *essence* data and *metadata*
- Essence
  - parts of content that directly represent program material such as audio, video, graphic, still-image, text, or sensor-data
- Metadata
  - parts of content that contain data used
    - » to *describe* essence or
    - » to provide information on its *use*
  - metadata objects sometimes called “mobs”
- Metadata may be
  - stored separately from the essence data
  - combined with the essence data (“embedded metadata”)

Source: AAF Developer Overview

Types of Multimedia Metadata

- Technical Metadata:
  - Form (data format, representation parameters like resolution, color depth...)
  - For live captured material: Time, date, location of original occurrence
  - Technical parameters of capture (e.g. aperture, exposure etc. for images)
- Content Description Metadata:
  - High level, structured:
    - » Title, author, composer, artist, cast, ...
  - High level, unstructured:
    - » Summary, textual description, thumbnail, ...
  - Low level:
    - » Objects and time positions
    - » Audio and video features: Key, mood, tempo ...
- Additional information:
  - Digital rights, classification, context, further links, ...

Types of Origin for Metadata

- Automatic creation or derivation:
  - All technical metadata
  - Extracted data features
    = mainly low level metadata (e.g. average brightness, musical tempo)
- Retrieval from external databases:
  - High-level metadata
  - Retrieval may be based on identifier or analysis of media content
  - Example: GraceNote database for music
- Manual addition
  - Archival, indexing, annotation, ...

Metadata Problems

- Creation metadata
  - During the creation of media essence, metadata is created but often ignored
  - Example: EXIF data in JPEG
- Manually added metadata
  - Users notoriously ignore the administration of metadata
- Metadata incompatibility
  - Metadata exists in various formats specific for media types, applications, product vendors, ...
  - Exchange of metadata is difficult
- Broad range of metadata
  - Metadata exists on various levels, covering all is expensive
- Metadata economy
  - How much of the metadata will be used?
  - When to create metadata?

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Troncy/Huet/Schenk, Multimedia Semantics - Metadata, Analysis and Interaction, Wiley 2011

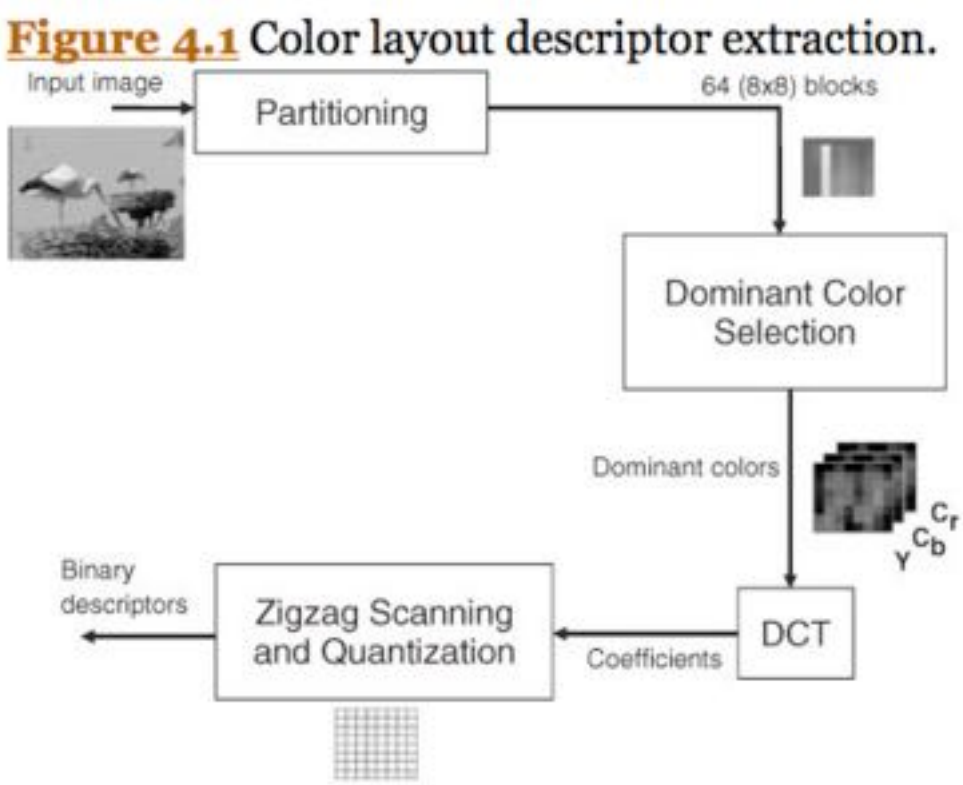
Chapter 4 of this book: R. Benmokhtar, B. Huet, G. Richard, S, Essid: Feature Extraction for Multimedia Analysis

Features of Multimedia Signals

- Feature: Condensed information from multimedia signal
  - Image, video, audio, text
  - Purpose: Description of content with *high variance* and *high discriminance*
  - Identification of similar content with respect to certain aspects
- Low-level features
  - Derived from signal processing algorithms
  - Selection of low-level features defined in MPEG-7 standard (see below)
- Multi-feature and multi-modal fusion:
  - Combined use of multiple characteristics
- Case study:
  - Automatic identification of violence in video material
  - Specifically scenes containing *punching*

Low-Level Visual Descriptors (Examples) (1)

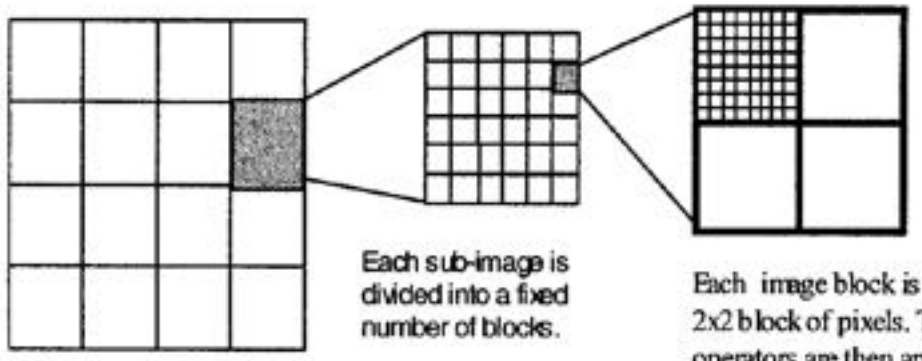
- Color Descriptors
  - Dominant Color Descriptor (DCD, Cieplinski 2000):
    - » Small set (four to eight) of dominant colors
    - » For each: Percentage, variance
  - Color Layout Descriptor (CLD, Kasutani and Yamada 2001):
    - » Representing spatial distribution of colors
  - Scalable Color Descriptor (MPEG-7 2001)
    - » HSV color space with fixed quantization (256 bins)
    - » Haar transform: compact and scalable



Source: Benmokhtar et al.

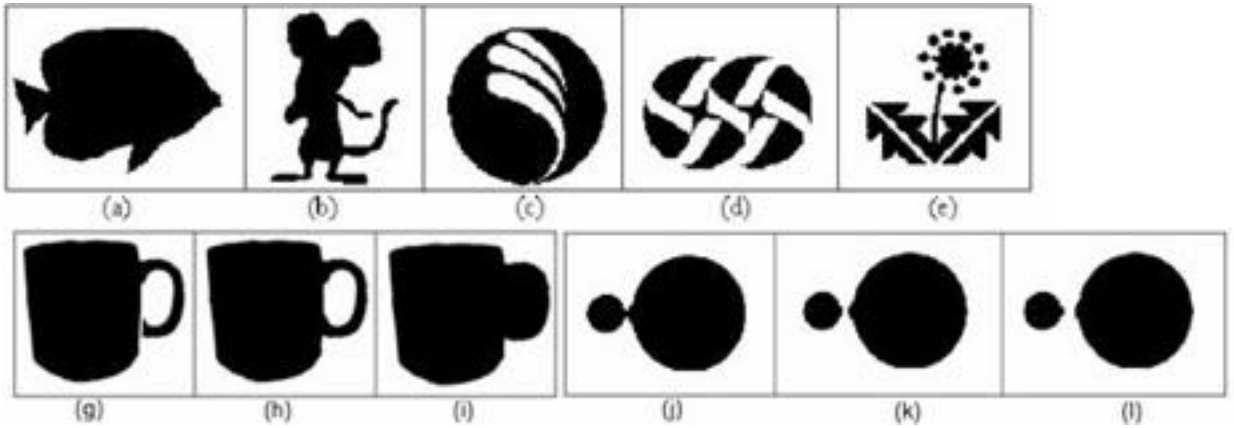
Low-Level Visual Descriptors (Examples) (2)

- Texture Descriptors
  - Homogeneous Texture Descripture (HTD, Manjunath et al. 2002)
    - » Statistical analysis on local spatial frequencies including direction
    - » 30 “channels” from 6 frequency times and 5 orientation channels
    - » Energy and energy deviation for each of the channels
  - Edge Histogram Descriptor (EHD, Park et al. 2000)
    - » For 16 subimages (4x4),
      detects five types of edges: horizontal, vertical, diagonal (2), isotropic
    - » 80-dimensional vector
    - » Spatial
      distribution of edges

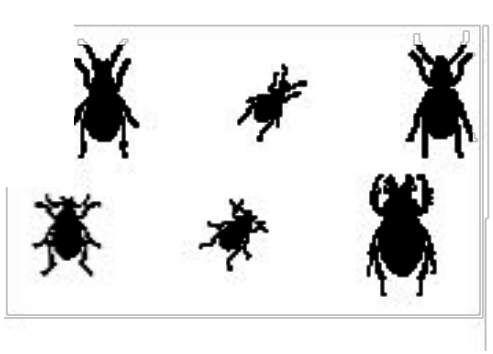


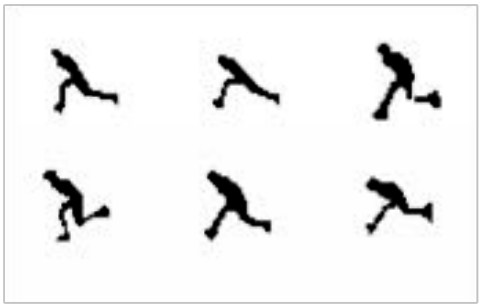
Examples for Shape Descriptors

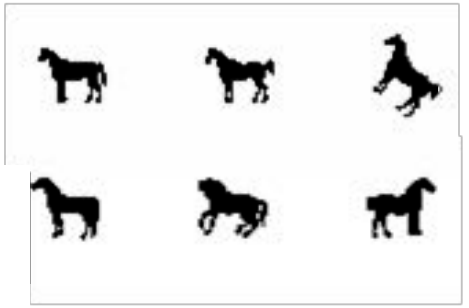
Region shapes:



Contour shapes:

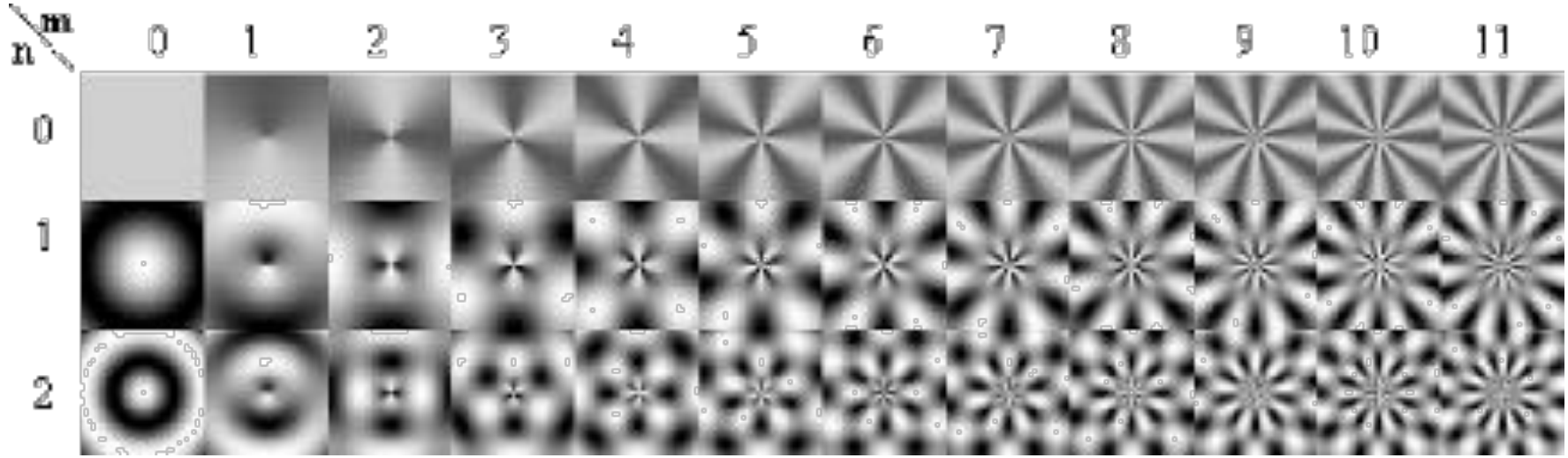






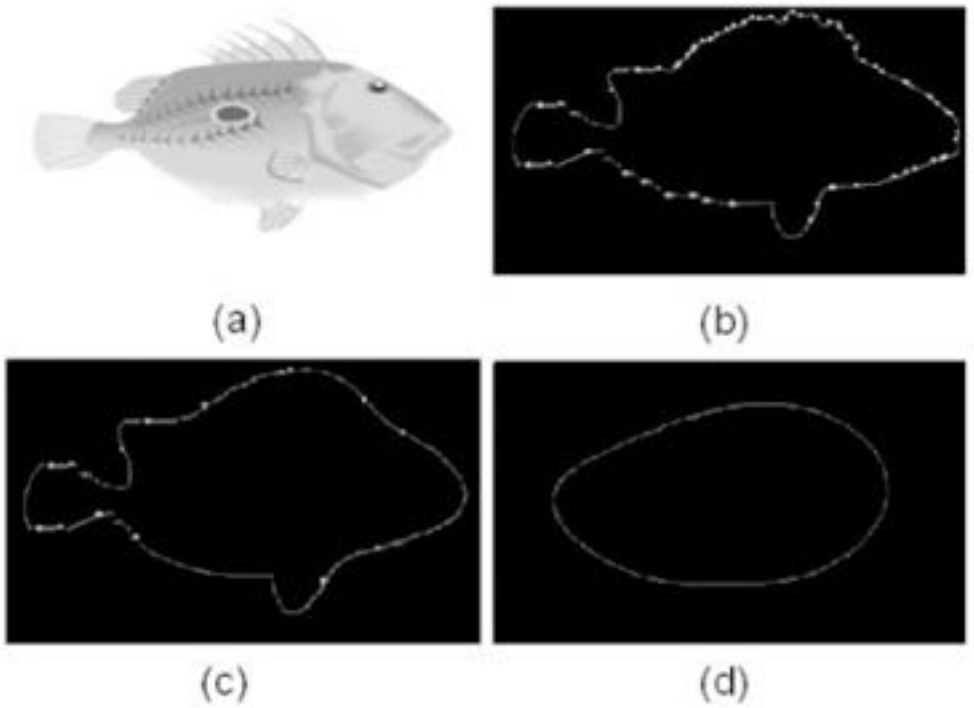
Angular Radial Transformation (ART)

- Region-based Shape Descriptor (R-SD, Manjunath et al. 2002)
- ART: Angular and radial parts of image information
  - Represent image as coefficients of basis functions
- First 36 base functions:



Curvature-Scale Space Computation

- Curvature is a local measure of how fast a curvature is turning
  - Contour is sampled with increasing precision and smoothed stepwise until a convex shape is obtained
  - During the step-wise smoothing, specific points are saved into the descriptor:
    - » Points separating convex and concave parts of contour
    - » Peaks of contour map
  - Additional global values:
    - » Eccentricity
    - » Circularity
    - » Number of CSS peaks
- Contour-based Shape Descriptor (C-SD, Zhang and Lu 2003)



Source: Benmokhtar et al.

Motion Descriptors for Video (Examples)

- Camera Motion Descriptor (CMD, Manjunath et al. 2002)
  - Camera operations:
    panning, tracking, tilting, booming, zooming, dollying, rolling
- Motion Actitivity Descriptor (MAD, Sun et al. 2002)
  - Statistical analysis of motion vectors from differential frames
  - *Intensity* of motion (motion vector magnitude)
  - *Direction* of motion (dominant direction of vectors)
  - *Spatial distribution* of activity
  - *Temporal distribution* of activity
- More complex descriptors describing long-term trajectories of objects

Case Study: Violence Detection in Video

- Only few descriptors are suitable
- Only combination of multiple descriptors can achieve results
- Possible solution:
  - Detection of human bodies using contour and region shapes
  - Detection of rapid and significant movements of persons and objects
  - Detection of bleeding using color descriptors
  - Combination with audio analysis (punch sound, screams)
- Combination of automatic pre-filtering of material with human analysis
- Important information extremely difficult to obtain through analysis
  - e.g. presence of (possibly concealed) weapons

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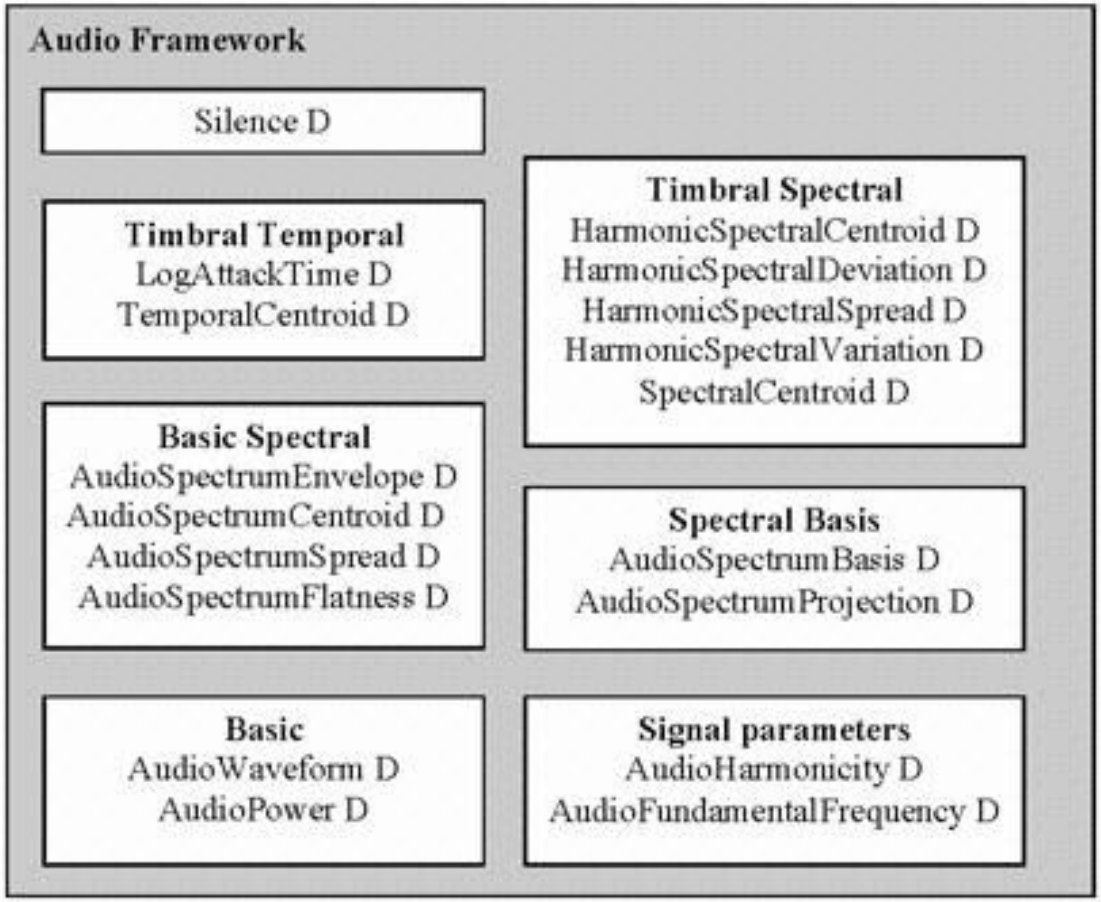
Literature:

Communications of the ACM 49(8), August 2006,
Special section on Music Information Retrieval, pp. 28-60

S. Dasiopoulou, E. Giannakidou, G. Litos, P. Malasioti, and Y. Kompatsiaris. 2011. A survey of semantic image and video annotation tools. In *Knowledge-driven multimedia information extraction and ontology evolution*, G. Paliouras, C. D. Spyropoulos, and G. Tsatsaronis (Eds.). Springer, 196-239.

Audio Low-Level Descriptors (MPEG-7 Examples)

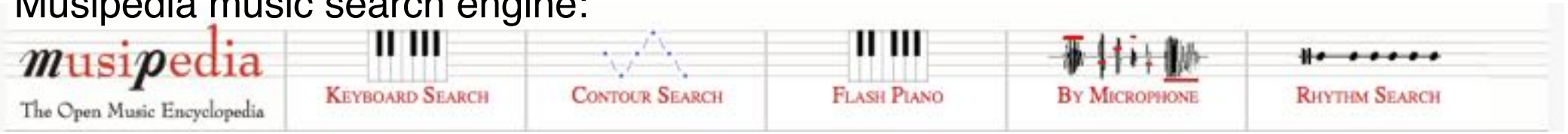
- Structures:
  - Single scalar value
  - Series of sampled values
- Features:
  - See figure
- MPEG-7 descriptions may contain features described using different (external) methods and algorithms



Audio High-Level Descriptors (MPEG-7 Examples)

- Audio signature
  - Statistical summary of spectral flatness descriptor
  - Fingerprinting, identification of audio content
- Musical instrument timbre
- Melody description
  - MelodyContour (terse, efficient)
  - MelodySequence
    - » Query by Humming
- General sound recognition and indexing
  - Probabilistic classifiers for sound classes
- Spoken content
  - Output and intermediate results of Automatic Speech Recognition (ASR)

Musipedia music search engine:

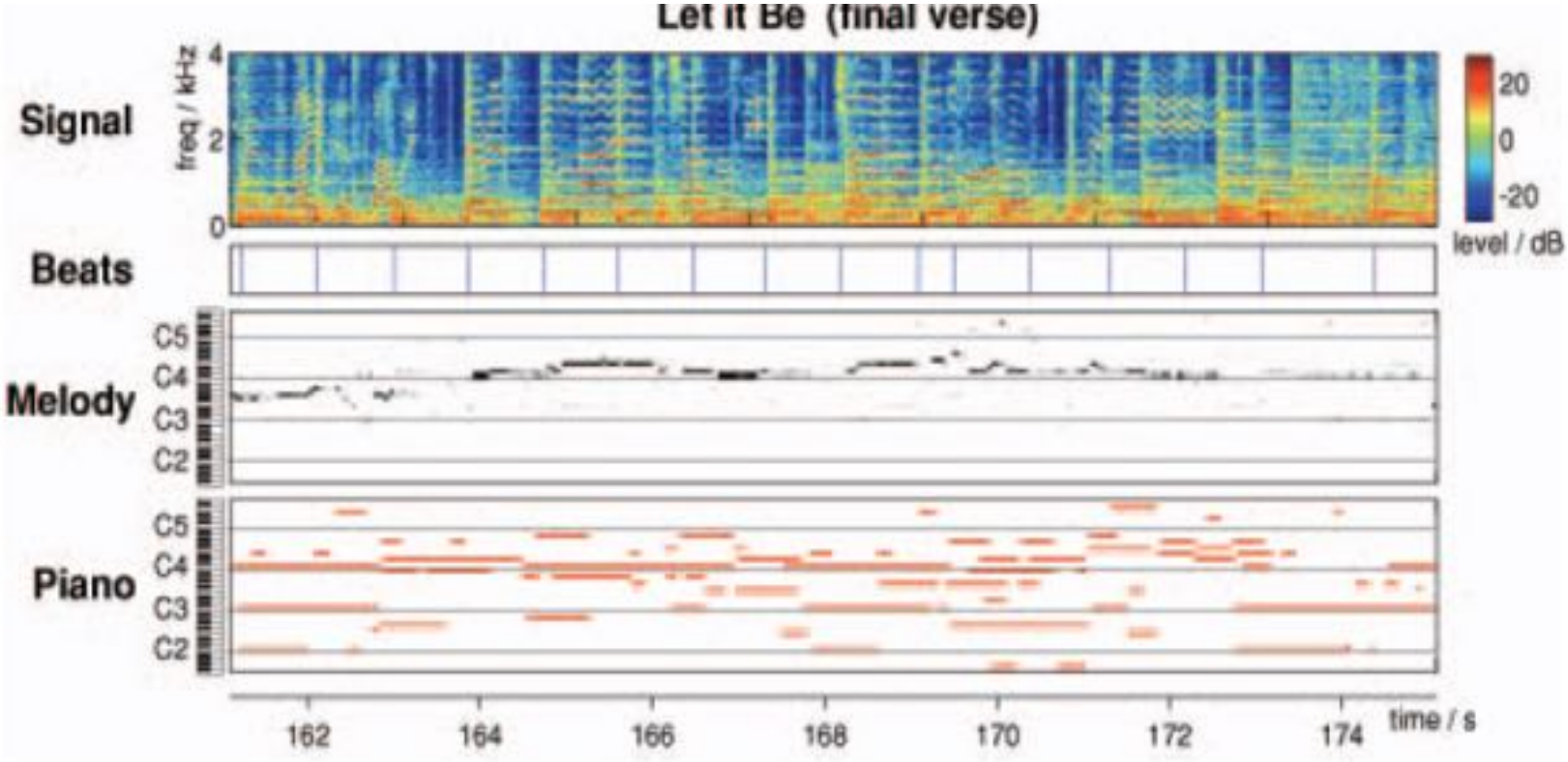


Timescales of Musical Information

- Individual music note events
  - Extraction of the music score
  - Identification of instrument playing
- Chords (simultaneous notes)
  - Identification of chords
- Phrase level
  - Tempo extraction
  - Identification of phrases (based on repetition/alternation of segments) e.g. identification of chorus
- Piece level
  - Genre identification (“rock”, “jazz”, “classical”)

Automatic Score Transcription

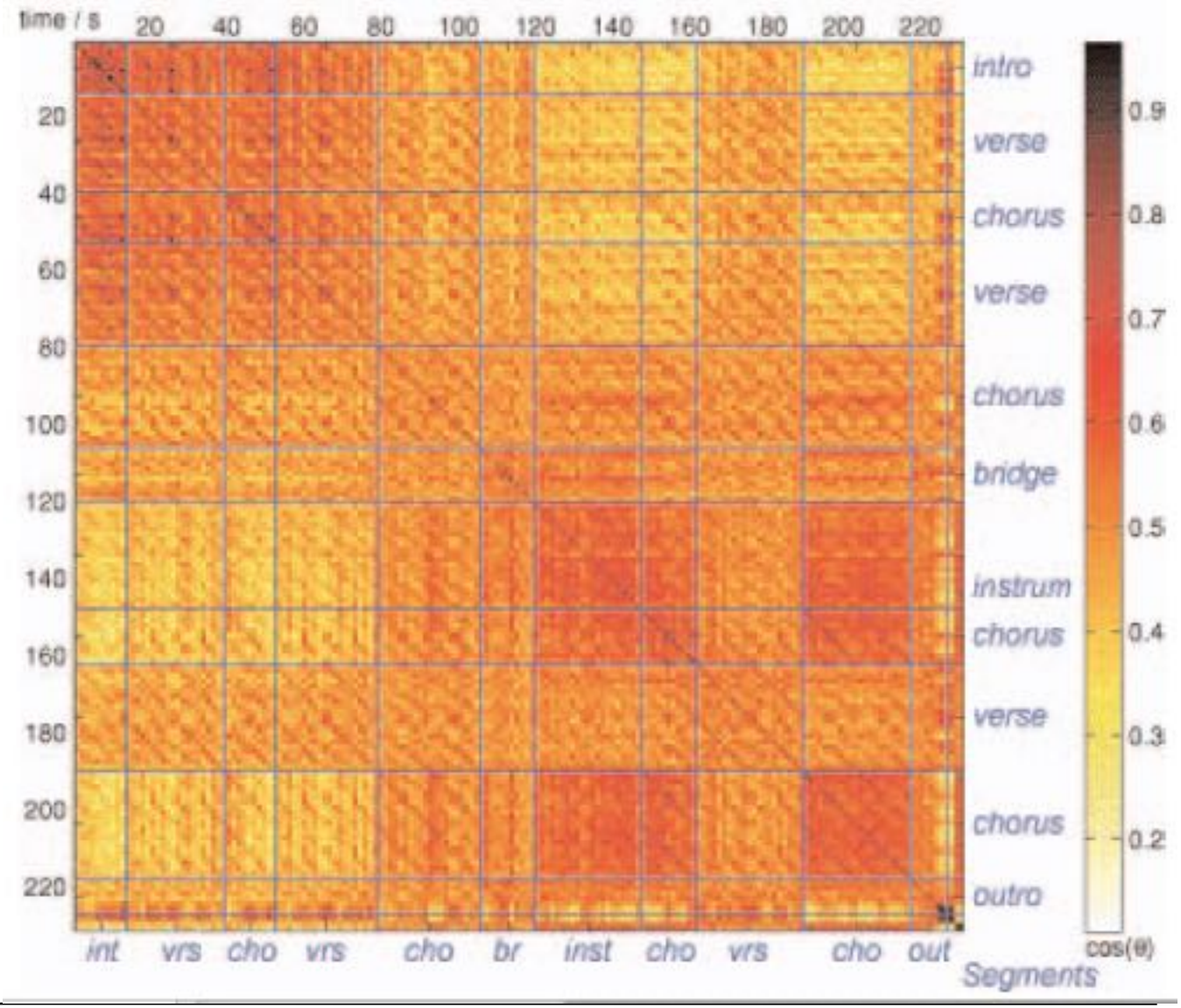
- Beats determined by tempo-smoothed event detector
- Melody recognized by general-purpose support-vector classifier
  - Trained to recognize spectral slices to be labelled with pitch values



Automatic Phrase Detection

- Self-similarity matrix
  - Values represent acoustic similarity
  - Looking for diagonal ridges off the main diagonal
  - Blue lines are manually inserted for comparison

See also:
http://www.fxpal.com/publications/FXPAL-PR-99-093.pdf



Example: Shazam Music Tagging (1)

- Commercial service for mobile phones:
  Identify music from a short audio sample *(query by example)*
  - See http://www.shazam.com (London, founded 2000)
  - A. Wang: The Shazam Music Recognition Service, *Comm. ACM* Aug. 2006
- Challenges:
  - Distinguishing music from noise
  - Dealing with distortions
  - Keeping fingerprints small (in order to deal with millions of songs)
- Basic idea:
  - Spectrogram peaks (energy distribution in time and frequency)[1]
  - Few “anchor” peaks are combined with peaks in a certain surrounding zone (time and frequency offsets)
    - » Combinatorial hashing creates 32b fingerprint hash token

[1] An overlapping Short-Time Fourier Transform is calculated at regular intervals on the audio data, and a power level is calculated for each resulting time-frequency bin. A bin is a peak if its power level is greater than all the other bins in a bounded region around the bin.

Example: Shazam Music Tagging (2)

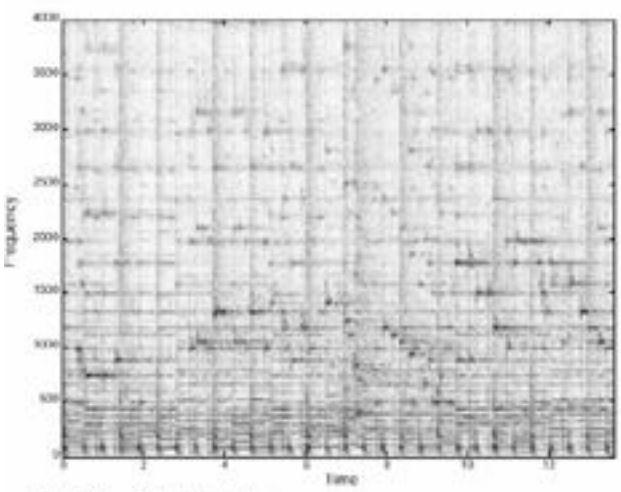


Fig. 1A - Spectrogram

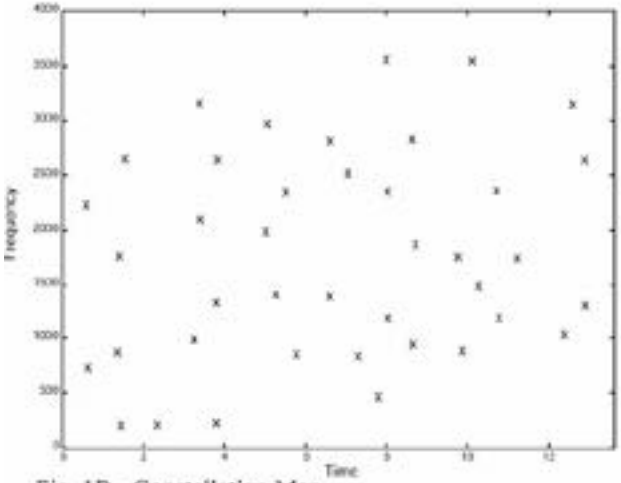


Fig. 1B - Constellation Map

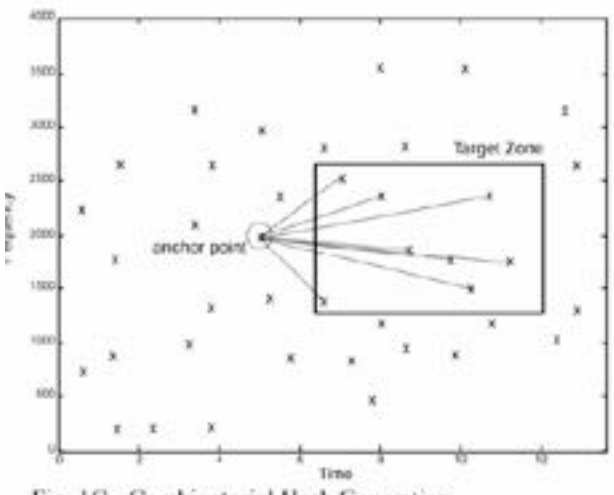


Fig. 1C - Combinatorial Hash Generation

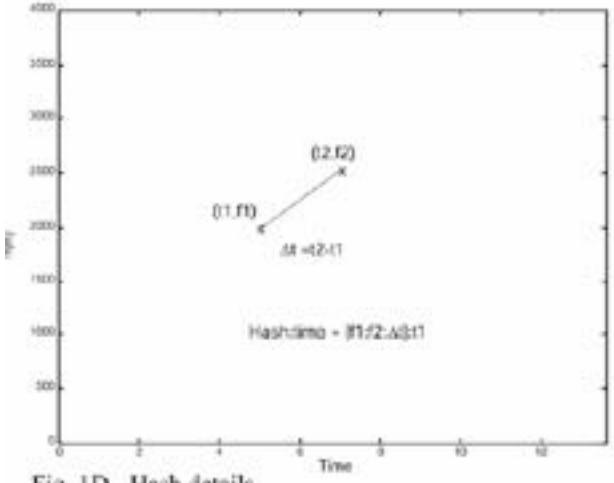


Fig. 1D - Hash details

http://www.ee.columbia.edu/~dpwe/papers/Wang03-shazam.pdf

Fingerprint Complexity Tradeoff

- Computing a more complex fingerprint:
  - Increases search time (more tokens to inspect)
  - Improves entropy
    - » Better descriptiveness distinguishes more clearly between items
- Shazam example:
  - Combinatorial expansion increases token number by factor 10 (roughly)
  - Combinatorial expansion accelerates index search by a factor of more than a million!

Example: Shazam Music Tagging (3)

- Comparing tokens from sample and database:
  - Only tokens having peaks from target signal are relevant
  - Even presence of a few well matching tokens is significant
- Temporal alignment of fingerprint features:
  - Matching set of features must have identical relative positions in time
  - Find linear time correspondence
    - » By searching a histogram of relative time differences for peaks

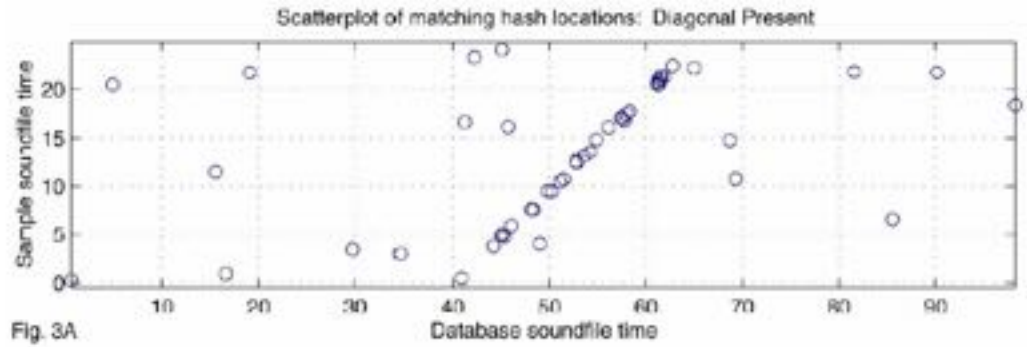


Fig. 3A

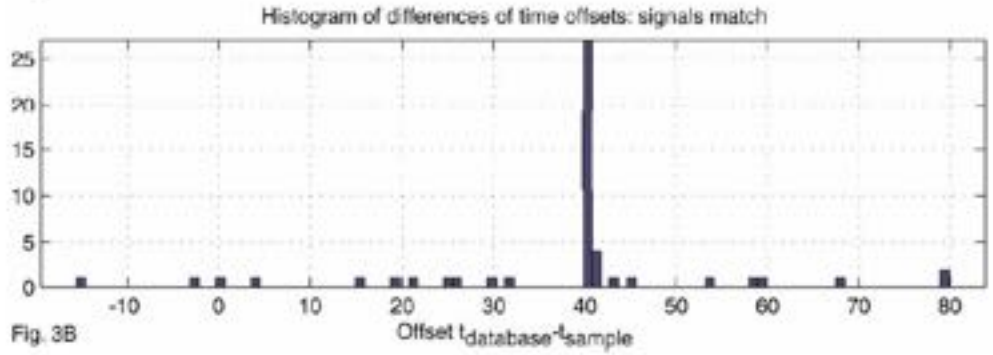


Fig. 3B

Example: Shazam Music Tagging (4)

- Commercial situation:
  - 2014: 20 million requests per day
  - 15 billion songs identified by 500 million users
- Without Internet connectivity (1999/2000):
  - Query via speech channel, result via text message
- Smartphone apps (Shazam/Encore)
  - Require Internet connectivity
  - Query and result via Internet
- Steady changes in business model:
  - Secondary content for TV
  - Music retail
  - Social music network

"2580" service

shazam.org

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Troncy/Huet/Schenk, Multimedia Semantics - Metadata, Analysis and Interaction, Wiley 2011

B. S. Manjunath, Philippe Salembier, Thomas Sikora: Introduction to MPEG-7, Wiley 2002

www.chiariglione.org, mpeg-7.joanneum.at, www.multimedia-metadata.info

MPEG-7

- Moving Picture Experts Group (MPEG)
  - = ISO/IEC JTC1/SC29/WG11 “Moving Pictures and Audio”
  - Main Web presence now: www.chiariglione.org/mpeg
- MPEG-7 “Multimedia Content Description Interface” (since 1996)
  - “ ... a standard for describing the multimedia content data that supports some degree of interpretation of the information’s meaning, which can be passed onto, or accessed by, a device or a computer code. MPEG-7 is not aimed at any one application in particular; rather, the elements that MPEG-7 standardizes support as broad a range of applications as possible.”
- ISO/IEC 15938 standard since 2002, parts still being added
  - MPEG 7 Audiovisual Description Profile (AVDP): 2012
- Industrial uptake very slow
  - Ambitious standard
- Some research and open source prototypes available
  - See e.g.
    http://mpeg7.joanneum.at,
    http://www.multimedia-metadata.info

Parts of the MPEG-7 Standard

- MPEG-7 Systems
- MPEG-7 Description Definition Language (DDL)
  - Descriptors (D) and description schemes (DS) specify the syntax and semantics of each *feature* (metadata element)
  - DDL allows the creation of Ds and DSs
    - » XML-based language with some small extensions to XML Schema
- MPEG-7 Visual
- MPEG-7 Audio
- MPEG-7 Multimedia Description Schemes
- MPEG-7 Reference Software
  - eXperimentation Model XM
- MPEG-7 Conformance (rules for conformance checking)
- Extraction and use of MPEG-7 descriptors
- MPEG-7 Profiles and Levels (Profile Schemas, Schema Definition)
- MPEG-7 Query Format

MPEG-7 Profiles

Part 9 of MPEG-7 (2005):

- Simple Metadata Profile (SMP)
  - Single document or simple collection, similar to EXIF or ID3
- User Description Profile
  - Tools for describing personal preferences and usage patterns
  - Adopted by TV-Anytime standard
- Core Description Profile
  - Collections of multimedia content, description of relationships

Later profiles:

- Audiovisual Description Profile (AVDP)
  - Targeted at requirements of audiovisual media production
  - Mainly driven by European Broadcasting Union (EBU)

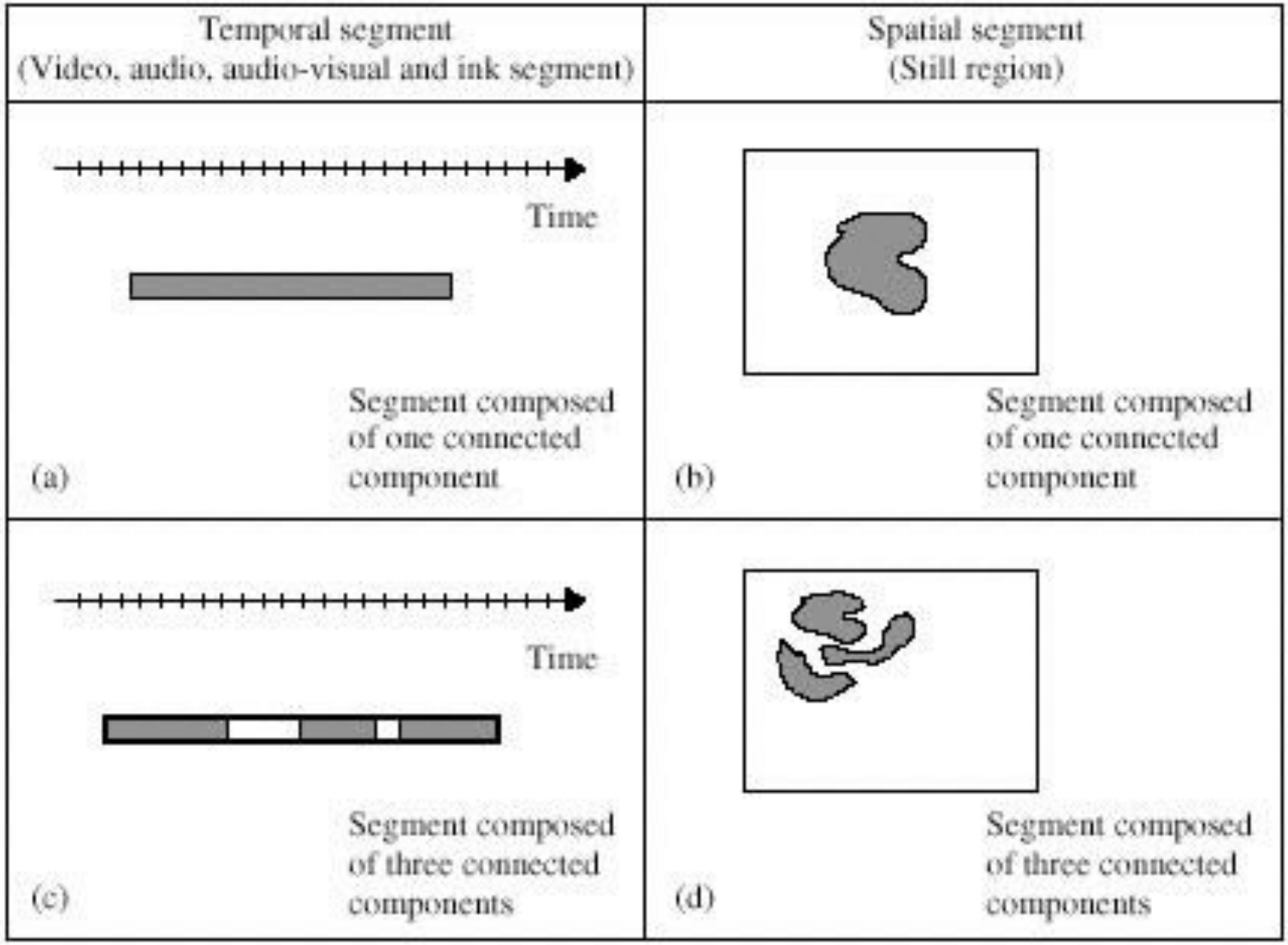
Application Areas of MPEG-7

- Architecture, real estate, and interior design (e.g., searching for ideas).
- Broadcast media selection (e.g., radio channel, TV channel).
- Cultural services (e.g., virtual museums).
- Digital libraries (e.g., image catalogue, musical dictionary).
- Education (e.g., repositories of multimedia courses).
- Home Entertainment (e.g., home video management).
- Investigation services (e.g., human characteristics recognition, forensics).
- Journalism (e.g. searching for video footage of political event).
- Multimedia directory services (e.g. yellow pages, tourist information).
- Multimedia editing (e.g., personalized electronic news service, media authoring).
- Remote sensing (e.g., cartography, ecology, natural resources management).
- Shopping (e.g., searching for clothes that you like).
- Surveillance (e.g., traffic control, surface transportation).
- ...

Structural Content Description: Segments

- A segment represents a section of an audio-visual content item.
- The Segment Description Scheme (DS) is an abstract class (in the sense of object-oriented programming).
- It has nine major subclasses:
  - Still Region DS (spatial)
  - Video Segment DS (temporal)
  - Moving Region DS (spatiotemporal)
  - Audio Segment DS (temporal)
  - AudioVisual Segment DS (temporal)
  - AudioVisual Region DS (spatiotemporal)
  - Still Region 3D DS (3D spatial)
  - Ink Segment DS (electronic ink from pen, smartboard etc.)
  - Multimedia Segment DS (composite of segments)

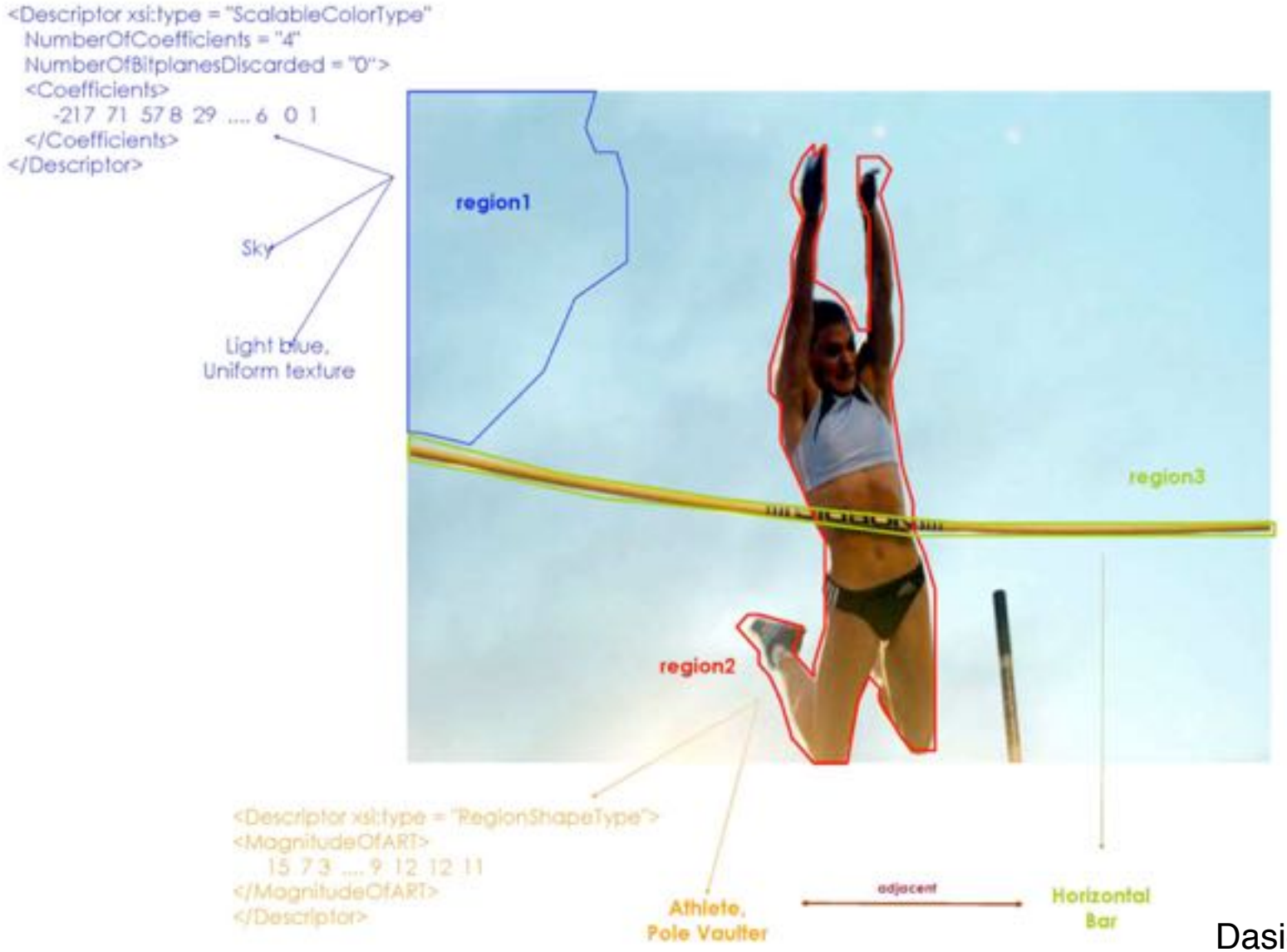
Examples of Segments



Structural Relations of Segments

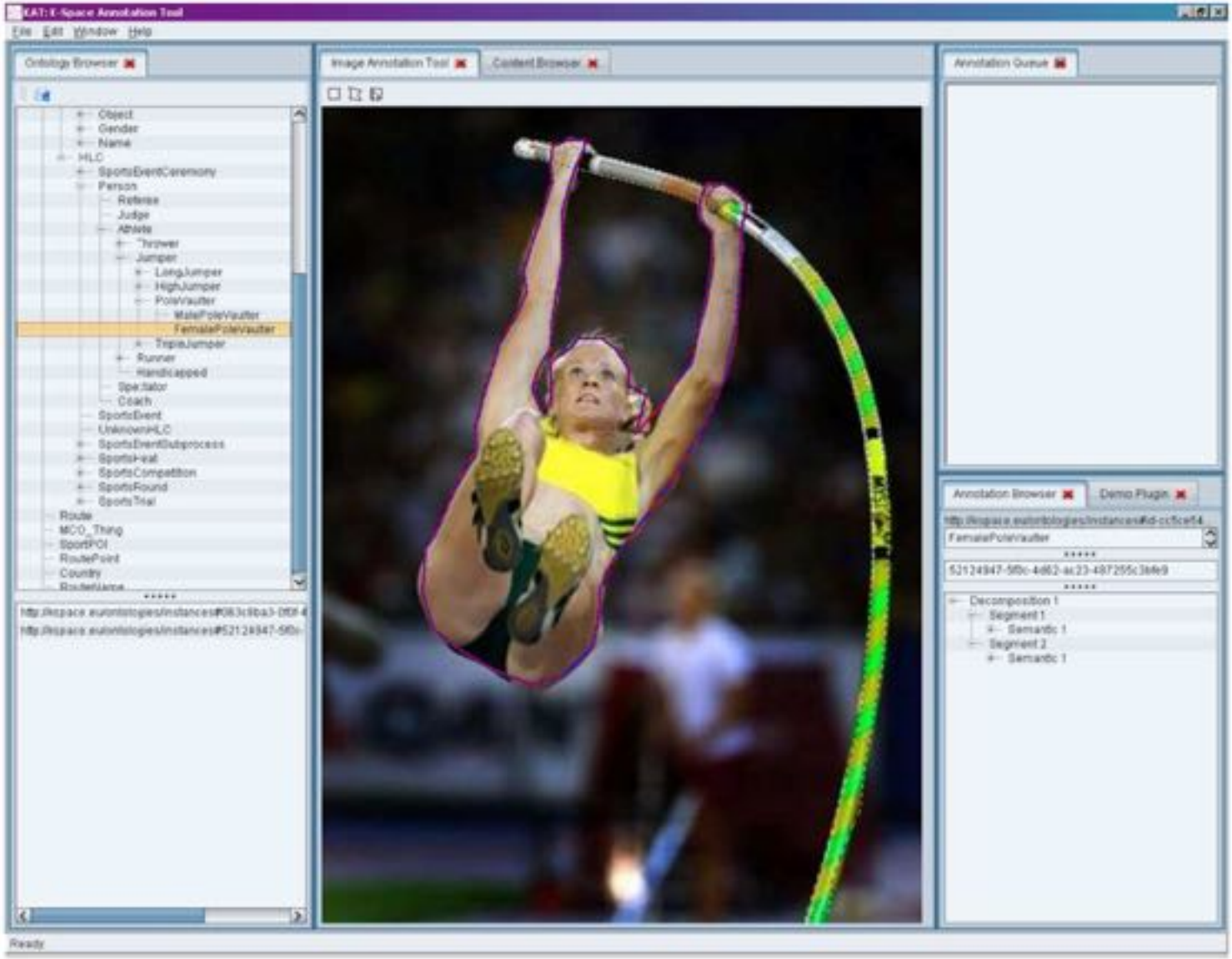
- Content structure:
  - Either hierarchical segment decomposition
  - Or general segment relationship graph
- Predefined structural relations in MPEG-7 (can be extended):
  - Generic:
    - » Identical, union, disjoint
  - Spatial:
    - » South, north, west, east, northwest, northeast, southwest, southeast, left, right, below, above, over, under
  - Temporal:
    - » Precedes, follows, meets, metBy, overlaps, overlappedBy, contains, during, strictContains, strictDuring, starts, startedBy, finishes, finishedBy, coOccurs, contiguous, sequential, coBegin, coEnd, parallel, overlapping
- For each relation, the inverse relation is implicitly defined.

Semantic Segmentation/Annotation of Images



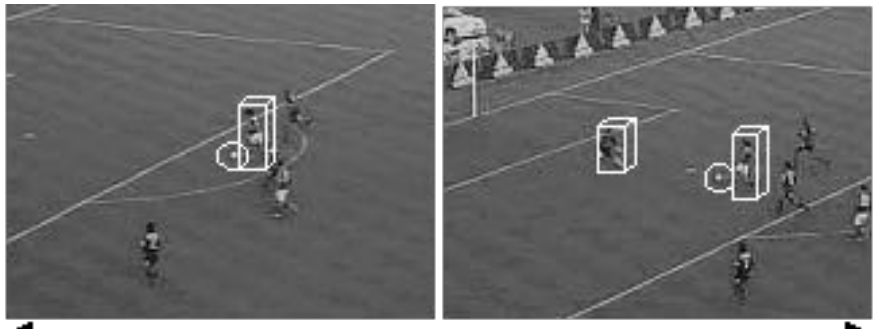
Dasiopoulou et al.

Example of Visual Annotation Tool

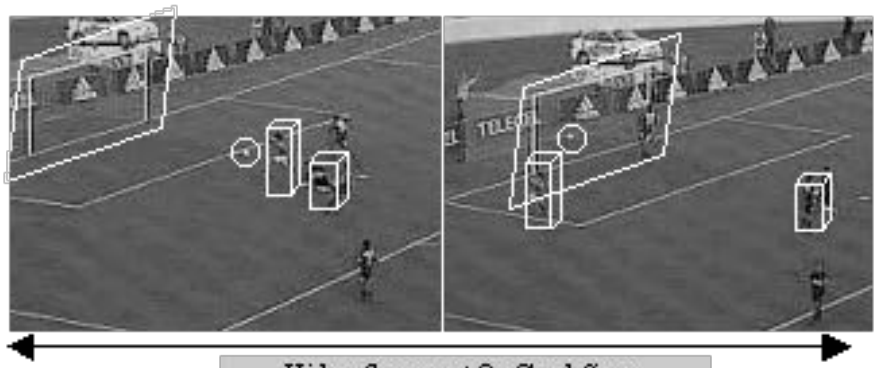


KAT tool
K-Space EU project

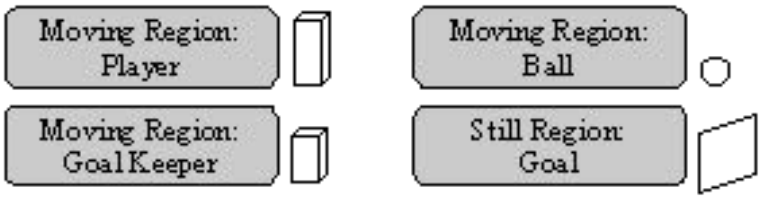
Video Segmentation with Moving Regions

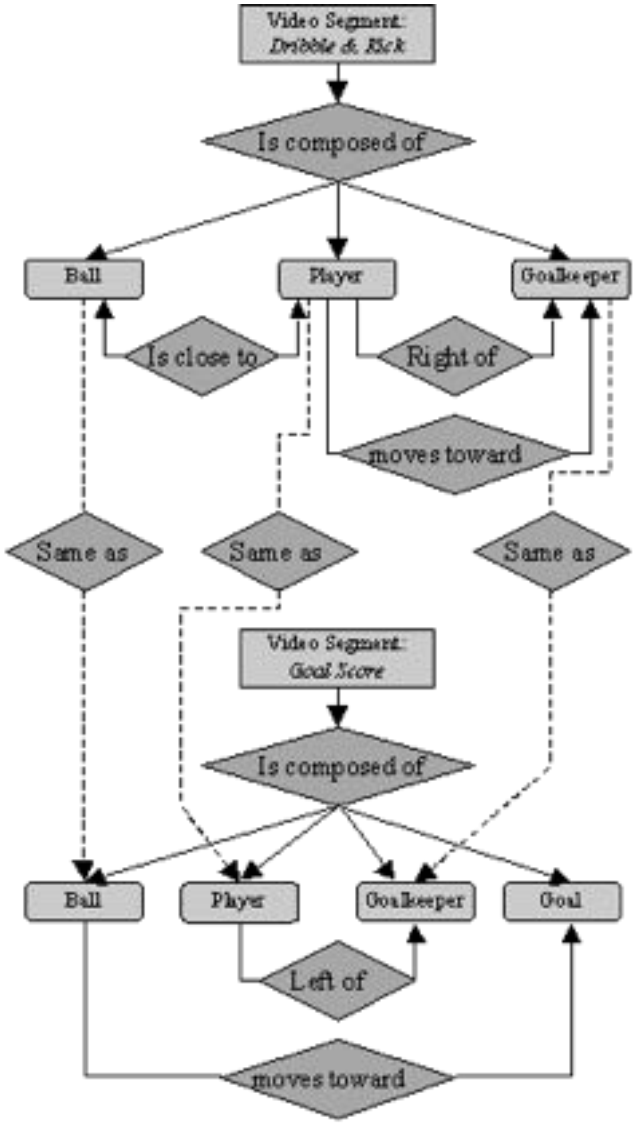


Video Segment: *Dribble & Kick*

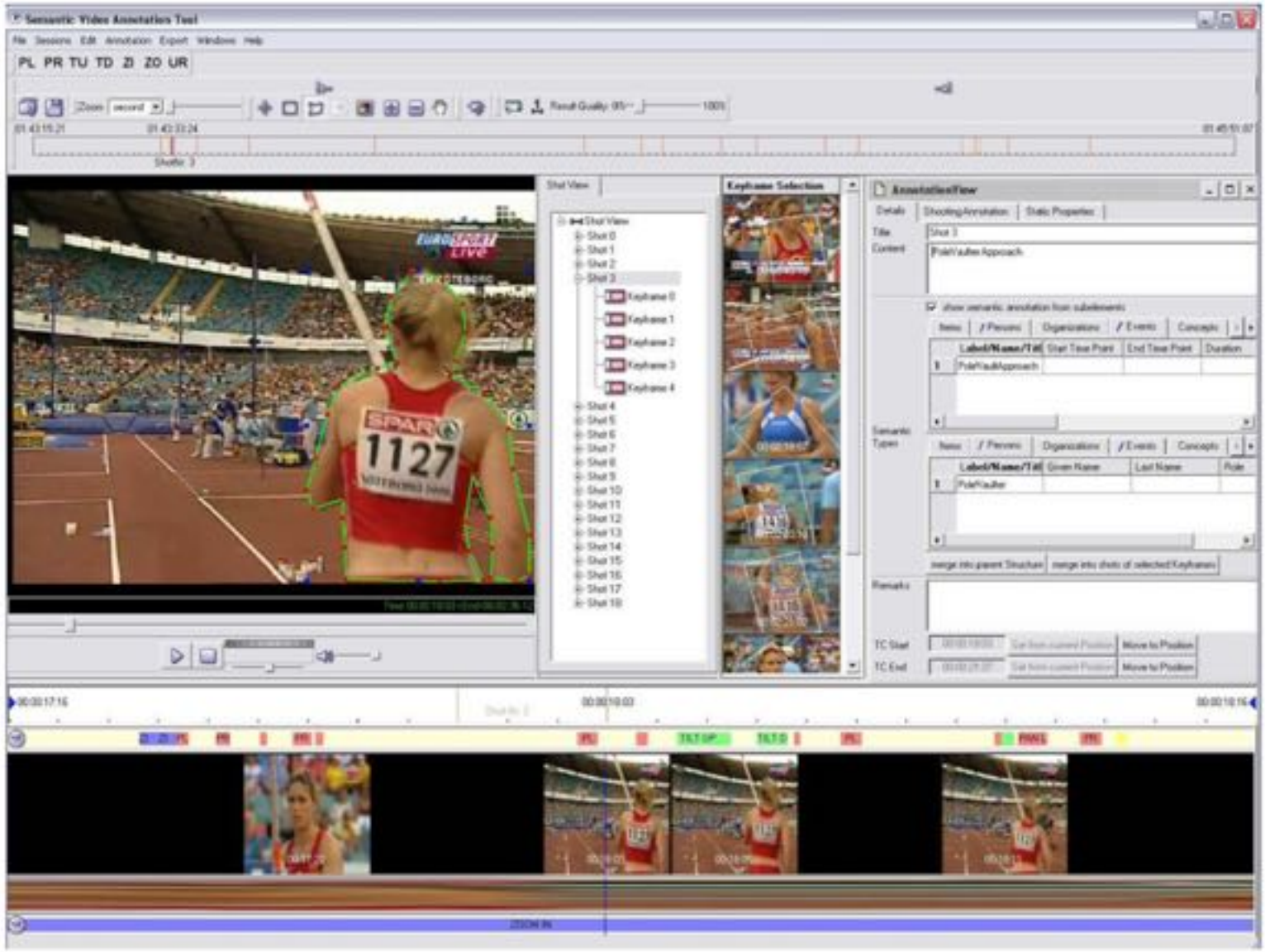


Video Segment 2: *Goal Score*



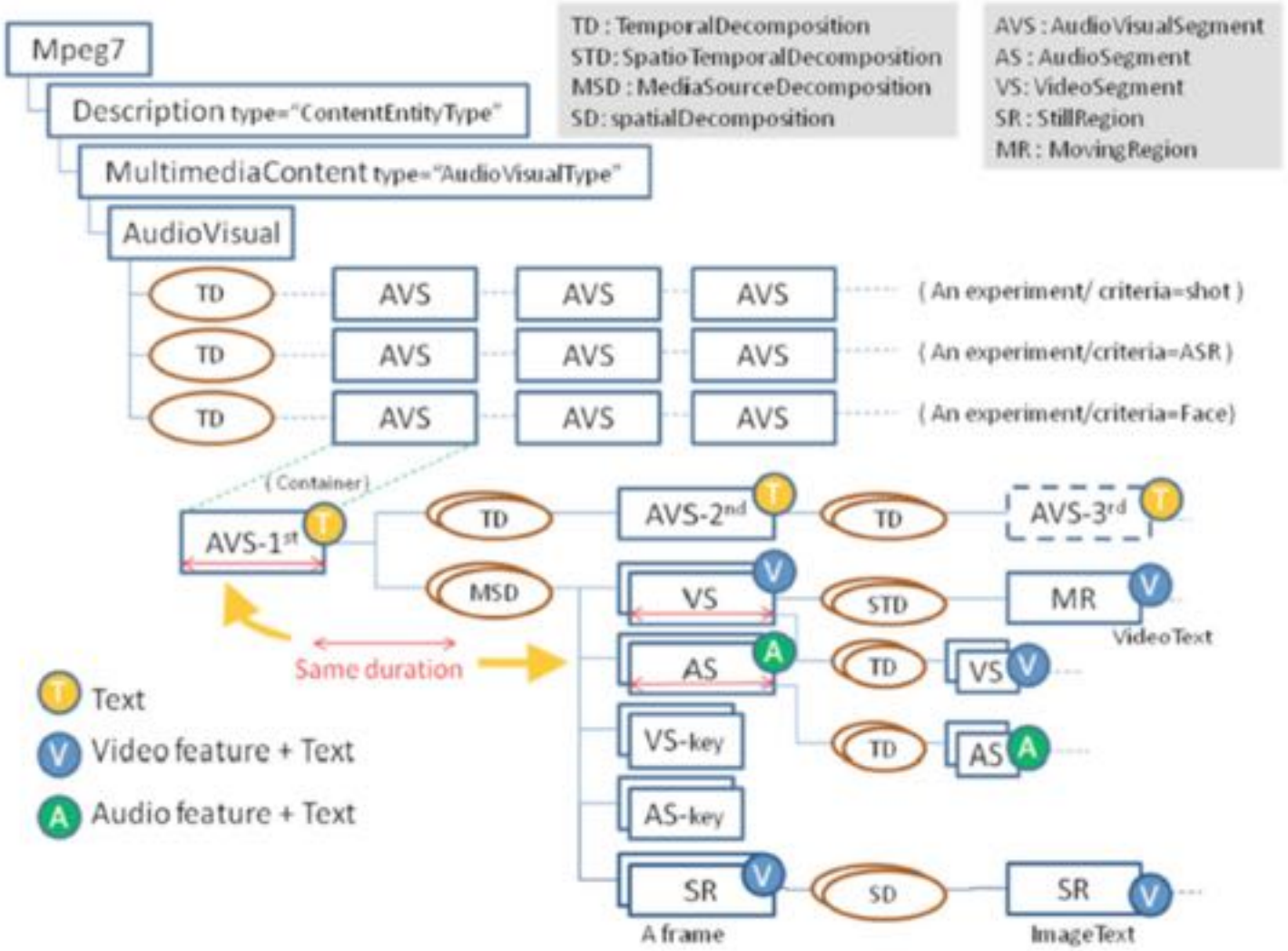


Example of Video Annotation Tool



Semantic Video Annotation Suite (joanneum.at)

Audiovisual Description Profile Structure



joanneum.at

Metadata in Classic Multimedia Formats

- EXIF (Exchangeable Image File Format)
  - EXIF header for captured image or sound
  - Massively used in still-picture cameras
- ID3 for MP3
  - ID3 tag: association of information frames (each for specific metadata)
  - Predefined frames: identification, technical metadata, rights, lyrics, …
  - Extensible by new frames
- News/G2
  - Developed by IPTC (International Press Telecommunications Council)
  - XML-based specific languages: NewsML-G2, SportsML-G2, EventsML-G2, ProgramGuideML-G2, WeatherML
  - Controlled vocabularies, e.g. IPTC News Codes

Selected Media Metadata Standards

- Dublin Core Metadata Initiative (DCMI) &
  PRISM (Publishing Requirements for Industry Standard Metadata)
  - Oriented towards books, magazines, journals etc.
  - Uses XML, RDF, Dublin Core
  - dublincore.org, www.prismstandard.org
- TV Anytime (tech.ebu.ch/tvanytime)
  - Devoted to audio-visual services making use of local mass-storage
  - Focus on Electronic Program Guide and user profiles
- EBU P/Meta
  - Devoted to material exchange between broadcasting stations
  - Vocabulary for program structure and metadata
- SMPTE Metadata Dictionary
  - Structured list of 1500 metadata elements, used e.e. in MXF format
- Commercial solutions e.g. by Rovi (www.rovicorp.com), *ex* Macrovision

METADATA INNOVATION

Dublin Core® Metadata Initiative

Index of Terms

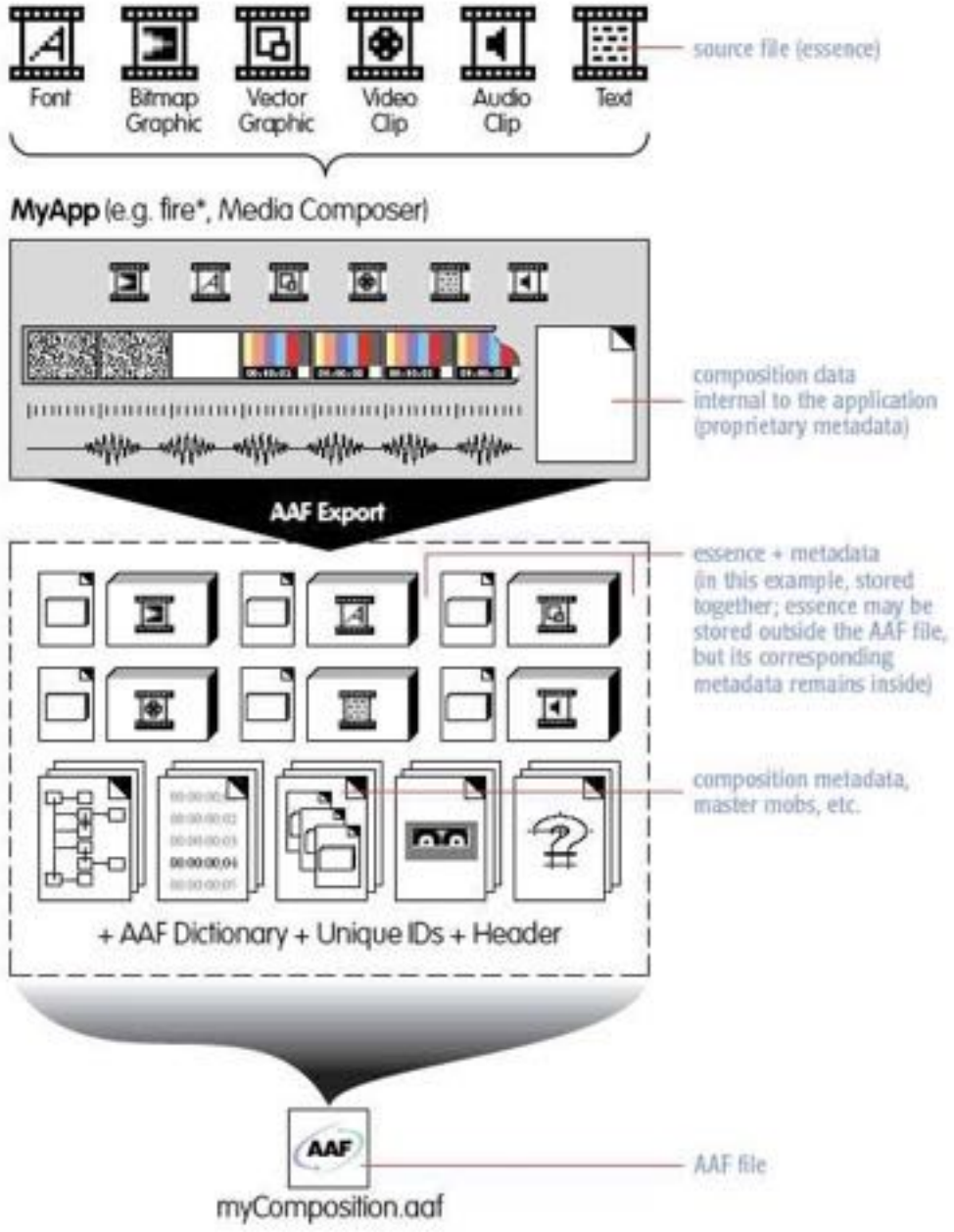
Properties in the */terms/* namespace	abstract , accessRights , accrualMethod , accrualPeriodicity , accrualPolicy , alternative , audience , available , bibliographicCitation , conformsTo , contributor , coverage , created , creator , date , dateAccepted , dateCopyrighted , dateSubmitted , description , educationLevel , extent , format , hasFormat , hasPart , hasVersion , identifier , instructionalMethod , isFormatOf , isPartOf , isReferencedBy , isReplacedBy , isRequiredBy , issued , isVersionOf , language , license , mediator , medium , modified , provenance , publisher , references , relation , replaces , requires , rights , rightsHolder , source , spatial , subject , tableOfContents , temporal , title , type , valid
Properties in the */elements/1.1/* namespace	contributor , coverage , creator , date , description , format , identifier , language , publisher , relation , rights , source , subject , title , type

Term Name:	**creator**
URI:	http://purl.org/dc/terms/creator
Label:	Creator
Definition:	An entity primarily responsible for making the resource.
Comment:	Examples of a Creator include a person, an organization, or a service.
Type of Term:	Property
Refines:	http://purl.org/dc/elements/1.1/creator
Refines:	http://purl.org/dc/terms/contributor
Has Range:	http://purl.org/dc/terms/Agent
Version:	http://dublincore.org/usage/terms/history/#creatorT-002
EquivalentProperty:	http://xmlns.com/foaf/0.1/maker

Integration of Digital Media in Video Production

- Example: Putting together all audio elements for a film soundtrack
  - Music tracks, ambient sound tracks, performer's synchronized sound, ...
  - Metadata related to creation process need homogeneous treatment
- Standards in the broadcasting industry
  - SMPTE (Society of Motion Picture and Television Engineers)
  - EBU (European Broadcasting Union)
  - Working on hardware-based standards for a long time
- EBU/SMPTE Task Force for Harmonized Standards for the Exchange of Program Material as Bit Streams (1996-1999)
  - Results further developed into Advanced Authoring Format (AAF)
  - AAF: Industry-driven, cross-platform, multimedia file format
  - "Advanced Media Workflow Association" (AMWA)
    - » see http://www.amwa.tv/

Interchanging Compositions with AAF



Adobe XMP

- Defined by Adobe 2001, since 2007 under BSD license
- Embedding of metadata into distributed files
  - In particular into PDF
- Data model and XML-Based storage model
  - Following the RDF description principle
- Formal schema definitions for metadata properties
- Application:
  - Adobe products (e.g. Photoshop, In-Design)
  - International Press and Telecommunications Council (IPTC) has integrated XMP into its Image Metadata specifications

8 Multimedia Content Description

Literature:

Troncy/Huet/Schenk, Multimedia Semantics - Metadata, Analysis and Interaction, Wiley 2011

W3C: RDF Primer, http://www.w3.org/TR/rdf-primer/

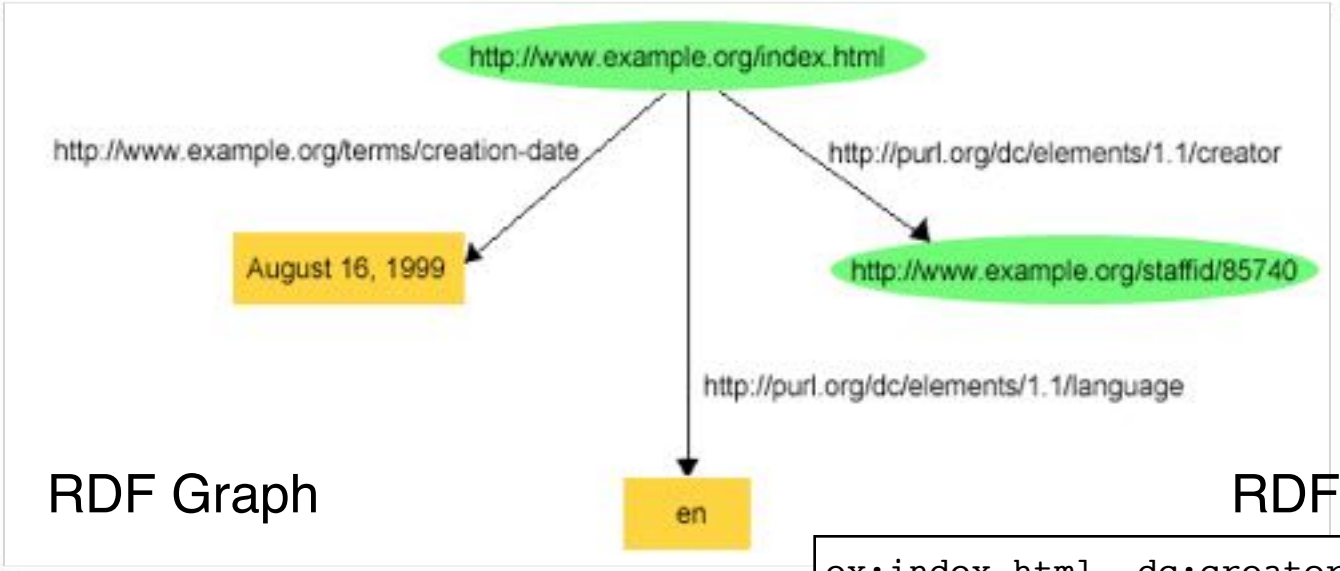
Resource Description Framework RDF

- Language for representing information about resources in the WWW
  - W3C's Semantic Web activity

- *Resource:* Anything that can be identified by a URI (e.g. all Web pages)
- *Property:* An attribute of a described thing which can take on specific values
- *Statement:* A triple consisting of
  - *Subject:* Some resource to be described
  - *Predicate:* A property of the subject
  - *Object:* A specified value
- Properties, values and statements are resources themselves,
  - i.e. can be identified by a URI
  - i.e. can be subject to further description
- RDF documents are collections of (triple) statements
  - written either in XML or in specialized notations (e.g. "Turtle")

RDF Example

- **http://www.example.org/index.html** has a **creator** whose value is **John Smith**
- **http://www.example.org/index.html** has a **creation-date** whose value is **August 16, 1999**
- **http://www.example.org/index.html** has a **language** whose value is **English**



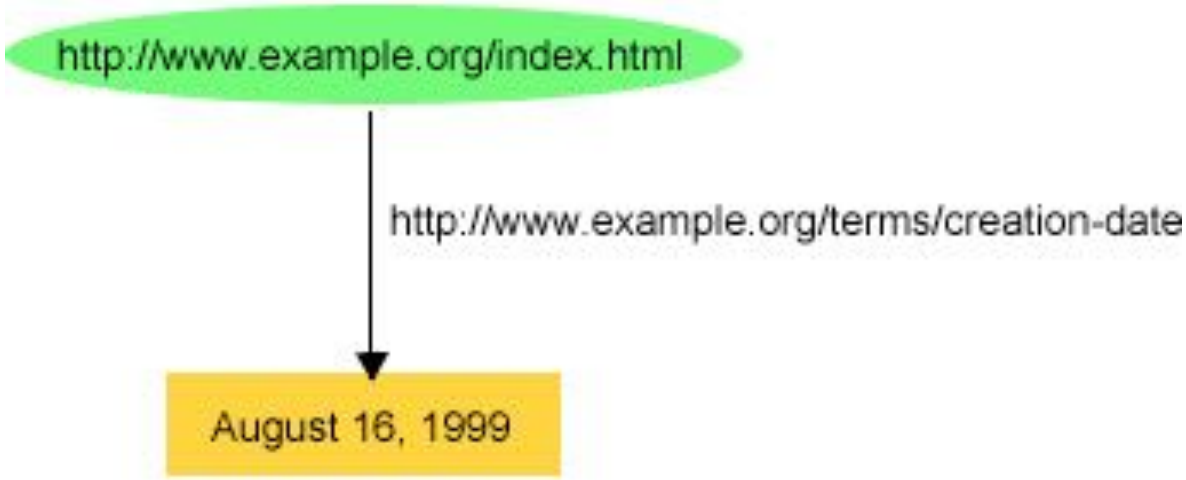
RDF Graph

RDF Triples (using namespaces)

```
ex:index.html   dc:creator              exstaff:85740 .

ex:index.html   exterms:creation-date   "August 16, 1999" .

ex:index.html   dc:language             "en" .
```

RDF/XML: XML Notation for RDF

```
<?xml version="1.0"?>
   <rdf:RDF
      xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
      xmlns:exterms="http://www.example.org/terms/">

      <rdf:Description
         rdf:about="http://www.example.org/index.html">
         <exterms:creation-date>August 16, 1999
         </exterms:creation-date>
      </rdf:Description>

   </rdf:RDF>
```



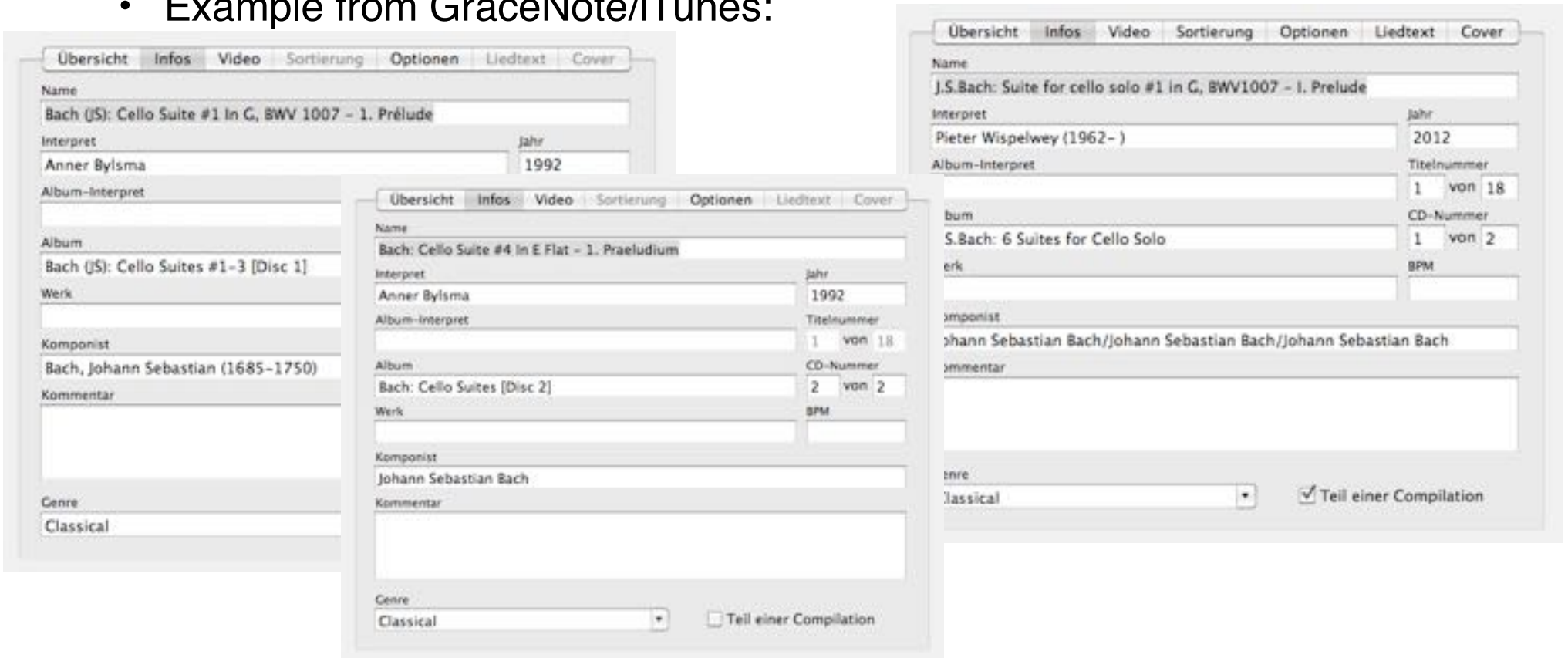
Example: Audio Metadata in DC-based RDF/XML

Multiple statements within one RDF description element

```
<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:dc="http://purl.org/dc/elements/1.1/">

  <rdf:Description
     rdf:about="http:www.medien.ifi.lmu.de/team/
     heinrich.hussmann/files/mmn8.mp4">
    <dc:creator>Heinrich Hussmann</dc:creator>
    <dc:title>Multimedia Content Description I</dc:title>
    <dc:description>Discusses multimedia metadata
     standards.</dc:description>
    <dc:date>2015-12-17</dc:date>
    <dc:format>audio/mp4</dc:format>
  </rdf:Description>

</rdf:RDF>
```

The Need for Ontologies

- Fixed schemata for text-based annotation are insufficient for practical purposes (or are often misused).
- Fine-grained and flexible semantic schemata are needed.
- Example from GraceNote/iTunes:



Defining Ontologies

- *Ontology*: Controlled vocabulary to express semantic information
  - Knowledge representation through concepts in terms of: types, properties, interrelationships
- RDF Schema
  - Simple set-theoretic ontologies, defines vocabularies for RDF
- OWL, Web Ontology Language by W3C
  - Extension of *RDF Schema*
  - Based on *Description Logics,* powerful mathematical semantics
  - Ontologies can be denoted in RDF syntax itself
- *W3C Ontology for Media Resources*
  - http://www.w3.org/TR/mediaont-10 (Recommendation Feb 2012)
  - Defines a standard terminology for multimedia segmenting and annotation
  - Gives detailed mappings for most commonly used metadata standards (incl. DC, EXIF, ID3, MPEG-7, QuickTime, YouTube, …)
  - Fully defined in OWL/RDF

Embedding Semantic Metadata into the Web

- RDFa: “RDF in Attributes”
  - Structured Data Markup for Web Documents
  - W3C WG Note August 2013, see http://www.w3.org/TR/xhtml-rdfa-primer/
  - Idea: Add information to Web documents on the meaning of its contents in machine-readable form
  - Applicable to all XML languages and HTML5
- Example:

```
<html>
 <head>...</head>
 <body> ...
        <h2 property="http://purl.org/dc/terms/title">
        The Trouble with Bob</h2>
        <p>Date:
        <span property="http://purl.org/dc/terms/created">
        2011-09-10</span>
    </p>...
 </body>
```

- Can be used, for instance, to add license conditions to links!