

Music and Multimedia Ontologies The Semantic Web

George Fazekas

g.fazekas@eecs.qmul.ac.uk

Queen Mary University of London

School of Electronic Engineering and Computer Science

Contents

- Recap: key points of the Semantic Web
 - Multimedia Ontologies
 - Why do we need ontologies for multimedia
 - Basic categories of multimedia information
 - Bibliographic and Social data
 - Time-based events and content annotation
 - CASE STUDY: Music Ontology and Workflow
 - Provenance and Trust
 - Harmonisation in the multimedia domain
-

Quick Recap

- Semantic Web:

- Enable machines to complete complex (search) tasks currently requiring human-level intelligence

- Basic building blocks:

- Logics and reasoning procedures
 - e.g. a Description Logic and Tableaux Calculus
 - Resource Description Framework
 - (subject-predicate-object) triples as basic model
 - URIs as identifiers, URLs for linking information
 - Ontology languages: RDFS / OWL
 - Shared conceptualisation of a domain
-

Quick Recap: Last lecture

- An Ontology is:
 - a shared conceptualisation of a world
 - Few types of ontologies:
 - **Domain ontologies:** domain or task specific (usually small)
 - **Upper ontologies:** include very generic concepts and may grow very big covering multiple domains.
 - **Core ontologies:** e.g. common part of an ontology library
-

Quick Recap: Last lecture

- Temporal information

- Allen's Calculus provides logically sound reasoning services
- DOLCE and OWL-Time provides for representing time intervals
- OWL-Time is commonly used by Linked Data services
- They allow for describing time intervals but do not support Allen's entailment rules

- Describing temporal information

- Recall the limitations of the RDF reification mechanism
 - Reification on the vocabulary level is often necessary to describe temporal information
-

Multimedia Content on the Web

- Two key factors:
 - Digital technologies have revolutionised media reproduction
 - e.g. coding standards like MP3 for audio and MPEG video
 - Advancements in network infrastructure allow fast, efficient and reliable transmission of multimedia content
 - As a result, there is a proliferation of multimedia content on the Web
 - We should be able to describe multimedia content on the Semantic Web:
but why?
-

Multimedia Content on the Web

- Some complex semantic query examples:
 - Find me movie clips where the lead actor of the movie I'm currently watching appears and dressed in black.
 - Find video segments where Fernando Torres scores against Germany as a Liverpool player.
 - Find me images of a red Ferrari pictured from the front.
 - Find me upbeat and catchy songs between 130-140 bpm, performed by artists collaborating in the London-Shoreditch area, and sort them by musical key.
-

Multimedia Content on the Web

- Some complex semantic query examples:
 - Machines can't yet perform all these tasks, partly due to the difficulties in large scale annotation of multimedia content.
 - However, automatic methods for media analysis are advancing fast.
 - The information needed to answer complex queries is often distributed across several data sources,
 - therefore semantic annotation and linking is essential.
-

Multimedia Related Information

- What is special about multimedia documents?
 - Multimedia documents (music, movies etc...) are perdurants.
 - Their parts are distributed in time.
 - We need support for qualitative reasoning as opposed to quantitative reasoning (and description):
 - work with regions of time and space
 - We need to conceptualise very diverse information:
 - People, Events, Time with multiple references, etc...
 - Multimedia documents are products of human intellectual work
-

Multimedia Related Information

- What should we be able to express about multimedia documents?
- Bibliographic Information
 - creator, author, title, date of publication, etc...
- Cultural and Social Information
 - cultural context and relationships (e.g. between creators)
- Information about media content
 - representation of qualities, features or events in the content
- Workflow Information
 - information about production (from idea to realisation)
- Provenance and Trust
 - origin and quality of information (this is more general)

Bibliographic information

- General information about products of intellectual works
- Existing vocabularies include:
- Dublin Core Metadata Element Set (DC)
 - 15 general terms including title, publisher, creator, contributor, date, etc...
- Bibliographic Ontology (BIBO)
 - defines concepts such as a book etc...
- example use of DC in the Bibliographic Ontology:

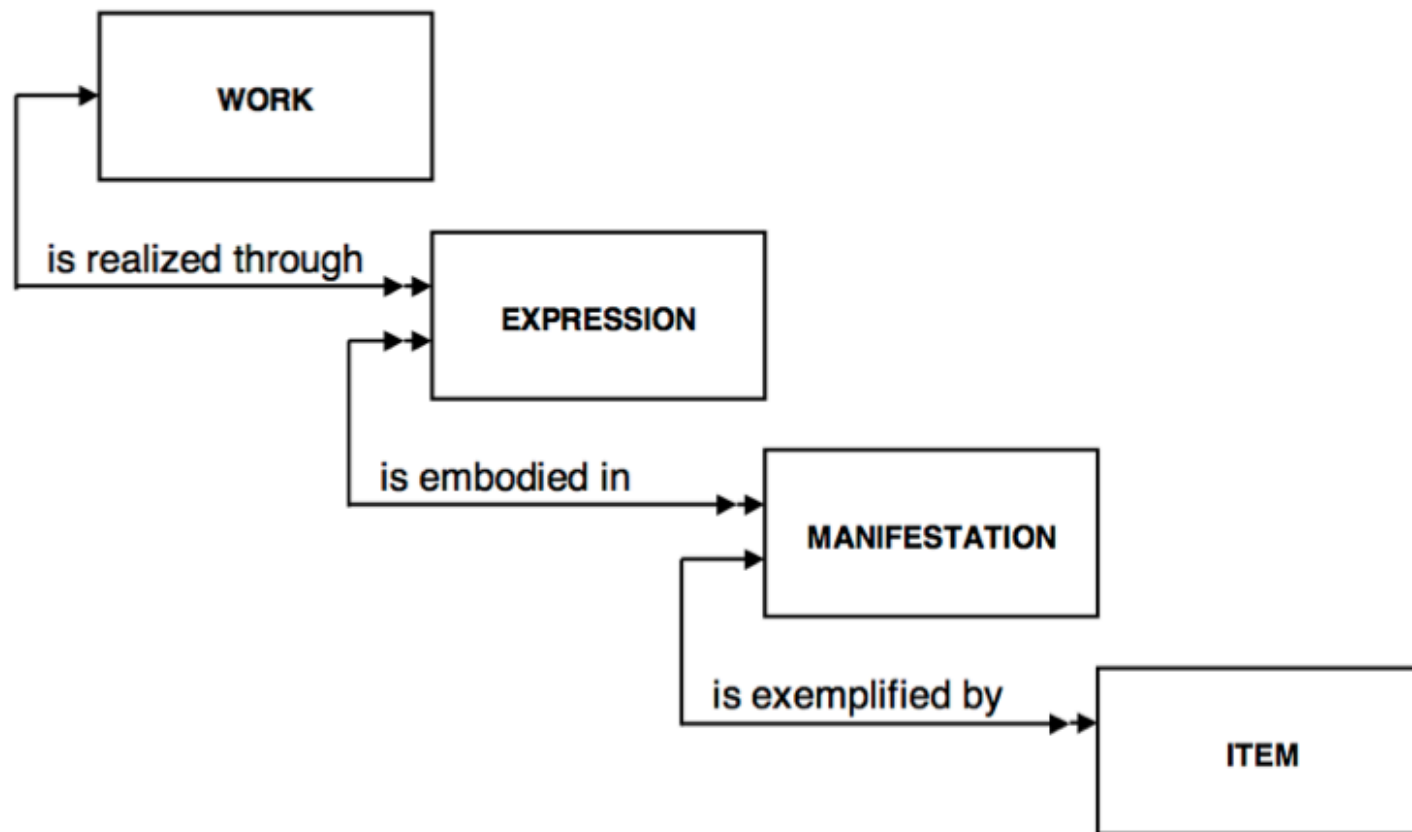
```
<urn:isbn:23983498> a bibo:Book ;  
    dc:creator <http://examples.net/contributors/2> ;  
    dc:title "Book Title"@en ;  
    dc:date "2000" ;  
    dc:publisher <http://ex.net/agents/1> .
```

Bibliographic information

- General information about products of intellectual works
 - Functional Requirements of Bibliographic Records (FRBR)
 - most conceptualisations directly relate media items with other entities, e.g. a book with its author and its shelf mark in the library, or an MP3 file on my computer and the band playing it.
 - FRBR goes further than describing single media items (e.g. a book, a movie) and provides a model for describing the life cycle of intellectual works.
 - It provides a 4 layer model ranging from abstract to concrete entities, e.g. a poem and an actual book it is printed in.
-

Bibliographic information

- General information about products of intellectual works
- Functional Requirements of Bibliographic Records (FRBR)



Bibliographic information

- General information about products of intellectual works
 - Work: an intellectual work on the most abstract level (e.g. a musical composition, but not its performance or a recording of it)
 - Expression: a realisation that remains intangible, but reflects common aesthetic qualities (e.g. a recital of a music piece)
 - Manifestation: physical embodiments of an expression, that bear the same characteristics (e.g. a particular edition of a book)
 - Item: a concrete item one may possess (e.g. I can't own all books printed in the 2nd edition, but I can own one or more items.)
-

Social and Cultural information

- Relationships between people and other things
- Many types of information may be classified as social or cultural
- For instance:
 - users listening habits at an online radio station
 - users buying habits at an online DVD retailer
 - collaborations between R&B music artist
 - etc..
- Most of this information concerns people
- The Friend of a Friend (FOAF) vocabulary was designed to describe relationships between people



<http://xmlns.com/foaf/spec/>

Social and Cultural information

- Friend of a Friend Vocabulary (FOAF)
- A machine readable vocabulary (published in OWL) for describing relationships between people, e.g. social networks.
- It defines concepts, for instance:
 - Agents (intelligent agents, humans or machines):
 - Person, Group, Organisation, etc...
 - Documents (e.g. an Image)
 - Online accounts
 - Projects (a collaborative work)
- and properties like:
 - name, made, maker, member, homepage, etc...



<http://xmlns.com/foaf/spec/>

Content information

- Representation of qualities, features or events in media
 - We need to be able to classify space-time regions within multimedia documents. e.g.
 - the chorus and the first verse of a song
 - the most tense moment of a movie
 - the elephant in the picture
 - We need to describe events in the course of the content
 - a car chase in a movie
 - the moment in a song when the bass guitar starts to play
-

Content information

- Representation of qualities, features or events in media
 - We need to relate events to different reference time coordinates
 - e.g. in a documentary about the second World War:
 - D-Day beginning at 6:30 AM [British Double Summer Time](#) (GMT+2) on Tuesday, June 6, 1944
 - D-Day is discussed exactly 40 minutes from the beginning of the documentary
 - e.g. a guitar solo:
 - recorded at 30 March 1963 at 11:30 at Abbey Road Studios
 - it starts at 1 min. 20 sec. after the beginning of the song
 - it starts at the 23rd minute on my compilation CD
-

Content information

- Timeline Ontology
- Recall OWL-Time: This allows the association of concepts with temporal entities such as instants or intervals.

:Jane a ex:Human .

:John a ex:Human .

:jjfriends a ex:Friendship ;

ex:member :Jane ;

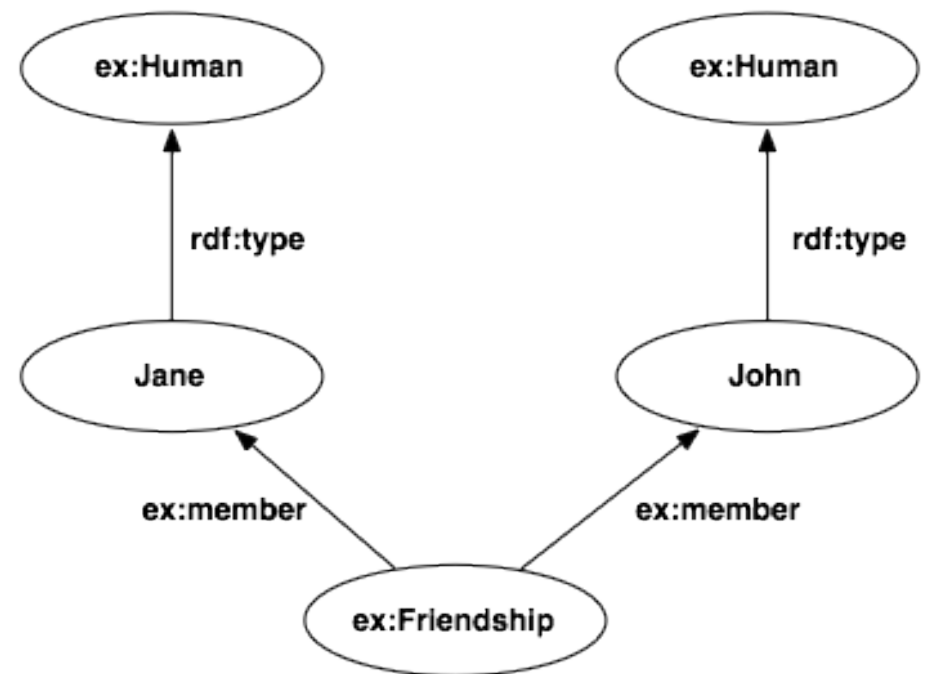
ex:member :John ;

**time:hasBeginning [
 a time:Instant ;
 time:inXSDDateTime "2002-11-05T18:00:00-5:00"**

];

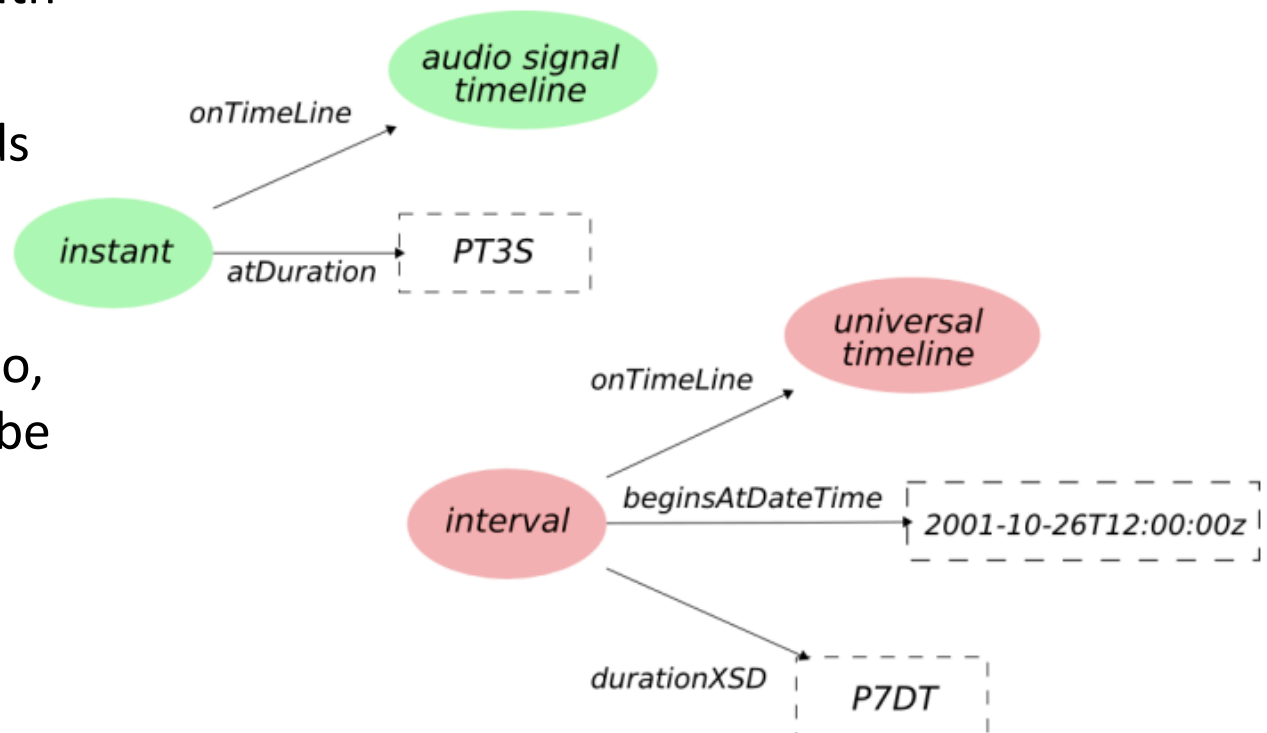
**time:hasEnd [
 a time:Instant ;
 time:inXSDDateTime "2012-03-15T20:00:00"**

].



Time-based events

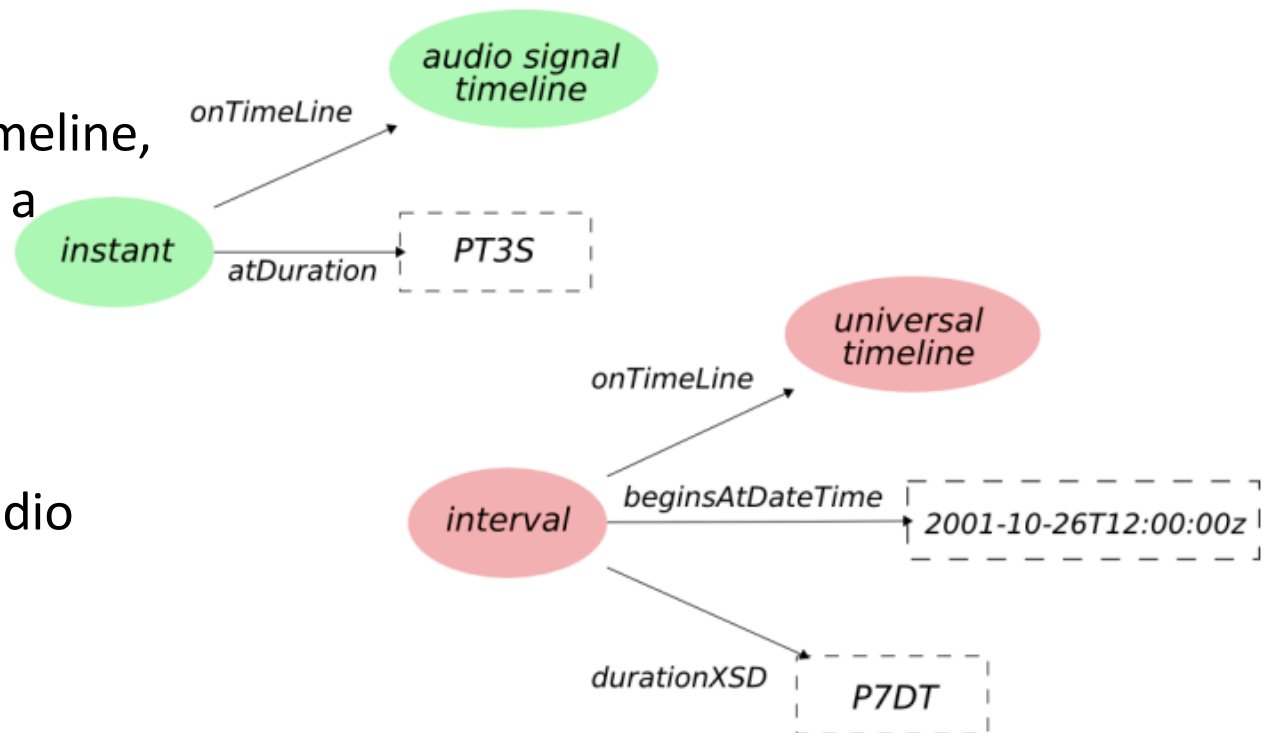
- Timeline Ontology
- we need multiple timelines with different coordinate systems
- The Timeline Ontology extends OWL-Time and defines the TimeLine concept.
- Temporal objects (signal, video, performance, work, etc.) can be associated with a timeline.



Time-based events

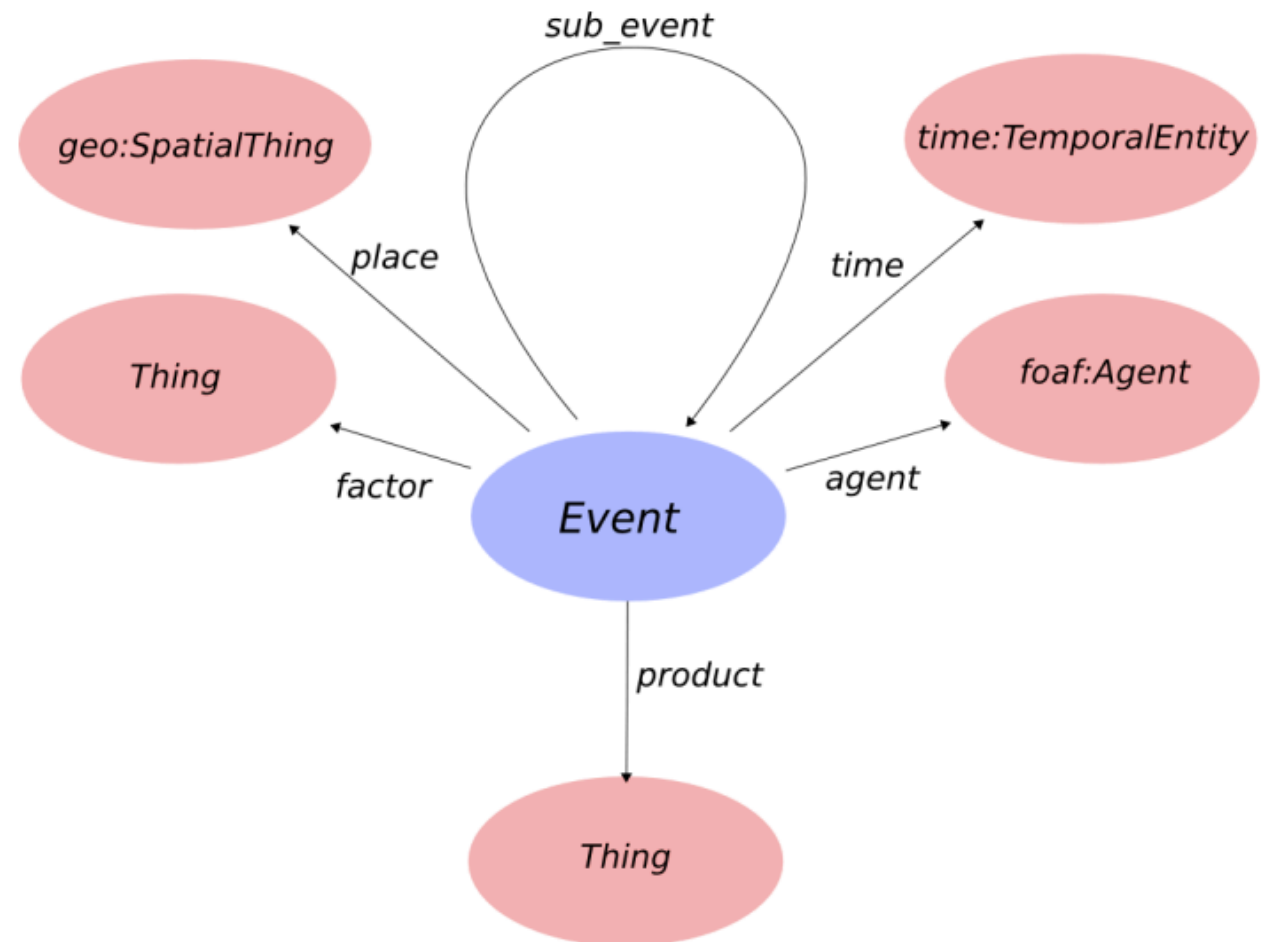
- Timeline Ontology

- timelines may be:
- concrete or abstract
- e.g. the universal physical timeline, or the timeline of the plot in a book or a musical work
- discrete or continuous
- e.g. a timeline describing a uniformly sampled digital audio signal is a discrete timeline



Time-based events

- Event Ontology
- relates arbitrary events to:
- temporal entities
- geographical coordinates
- participating agents
- passive factors (such as tools)
- and products (results of an event)
- allows to decompose complex events into sub-events



<http://purl.org/NET/c4dm/event.owl#>

Time-based events

- Event and Timeline Ontology example

- a musical example:
- Describes an event (a recording session) relative to a universal timeline,
- and a particular recording event described as a sub-event of the recording session.

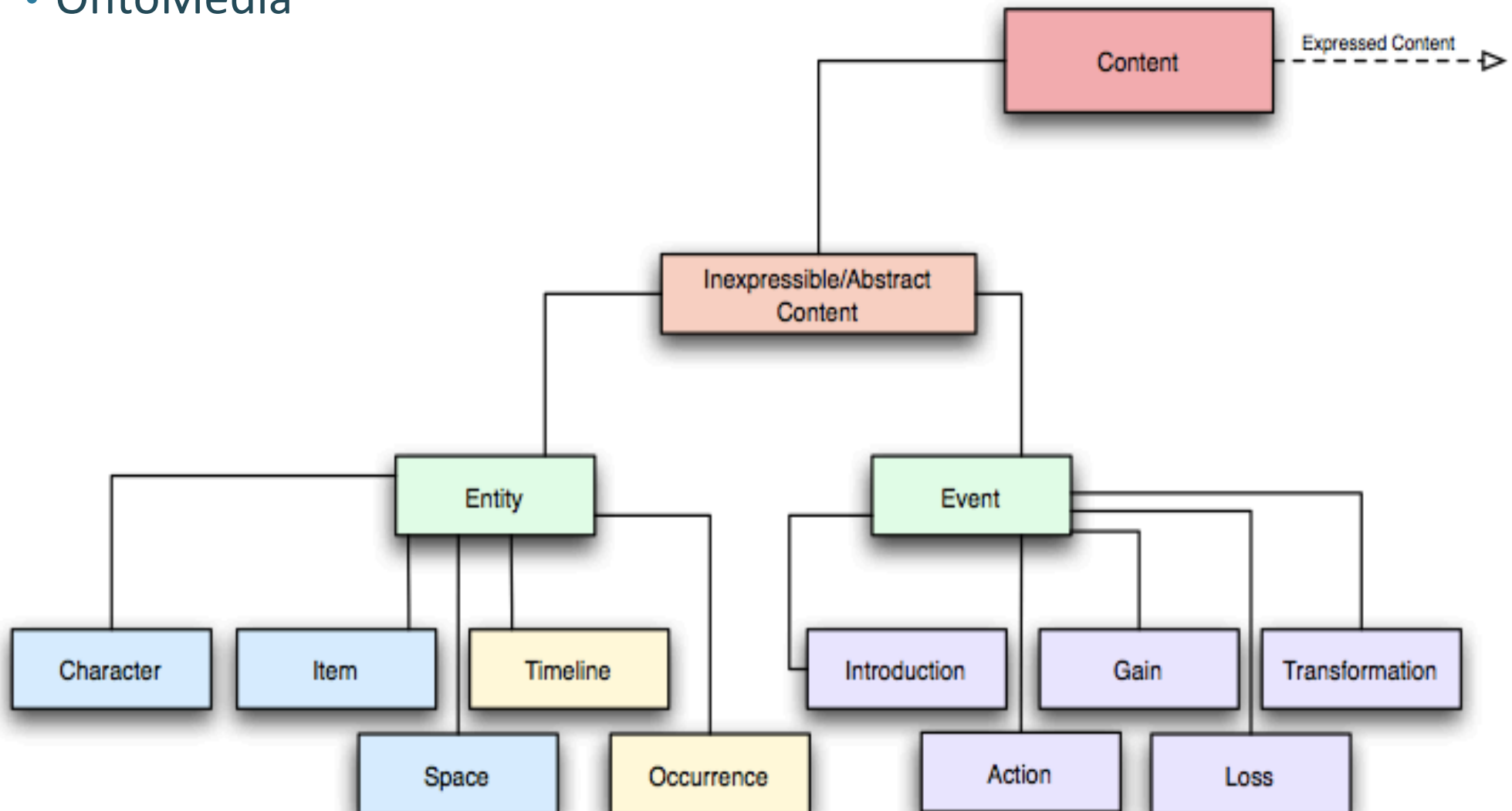
```
:recording_session a event:Event ;  
    event:place <http://example.org/my_studio> ;  
    event:agent <http://foaf.me/soundengineer#me> ;  
    event:time [  
        a tl:Interval ;  
        tl:timeline tl:universaltimeline ;  
        tl:beginsAtDateTime "2012-03-30T10:00:00Z"^^xsd:dateTime ;  
        tl:durationXSD "P1DT"^^xsd:duration  
    ] ;  
    event:sub_event :recording_event ;  
    event:product <http://example.org/album> .  
  
:recording_event a event:Event ;  
    event:factor [ rdfs:label "Microphone" ] ;  
    event:product <http://example.org/signal> .
```

Content annotation

- OntoMedia
 - The OntoMedia ontology is designed to describe fiction, e.g. the plot of a book or a movie, including time-based events that influence the characters.
 - It uses a similar Event-based conceptualisation as the Event and Timeline ontologies, but it isn't directly connected to them
 - It may describe interaction between people:
 - character development
 - travel etc...
 - Generally, entities and events represent the elements present in a media and the situations in which they are present.
-

Content annotation

- OntoMedia



Workflow information

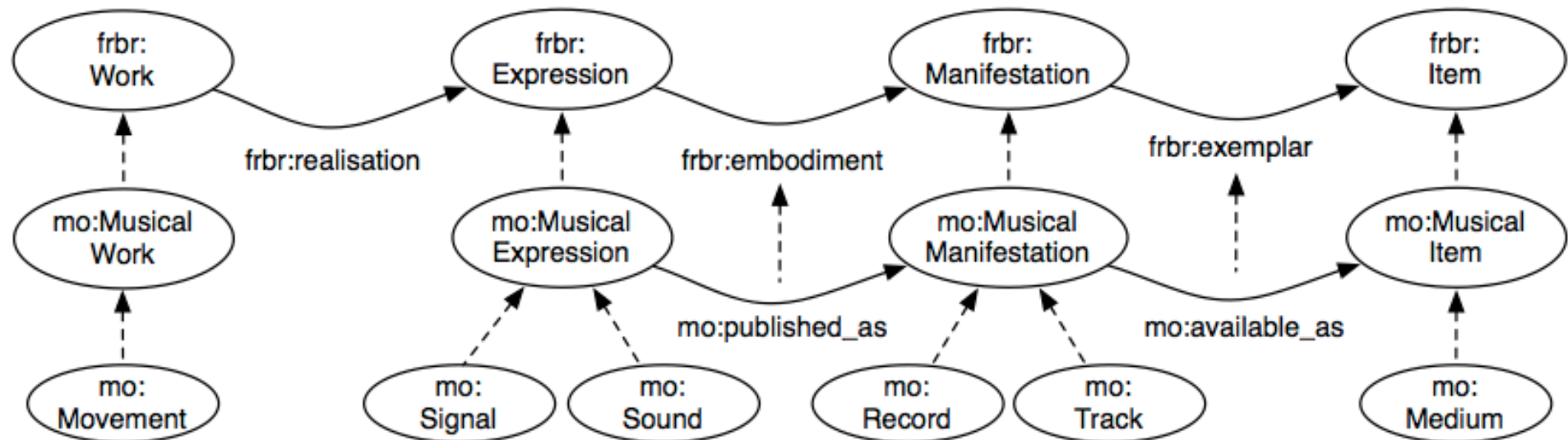
- information about an intellectual endeavour (media production from the idea to realisation)
 - Describe how multimedia documents, that is, intellectual works are created from the initial idea and abstract realisations to concrete items such as a movie you can buy on DVD, or a musical piece you can buy on CD.
-

Workflow information

- information about an intellectual endeavour (media production from the idea to realisation)
 - Describe how multimedia documents, that is, intellectual works are created from the initial idea and abstract realisations to concrete items such as a movie you can buy on DVD, or a musical piece you can buy on CD.
 - Recall the 4 layer FRBR model ranging from abstract to concrete entities: Work, Expression, Manifestation, Item.
 - How could we describe how we move from abstract to concrete?
 - e.g. how Beethoven's 9th Symphony becomes available on a CD?
-

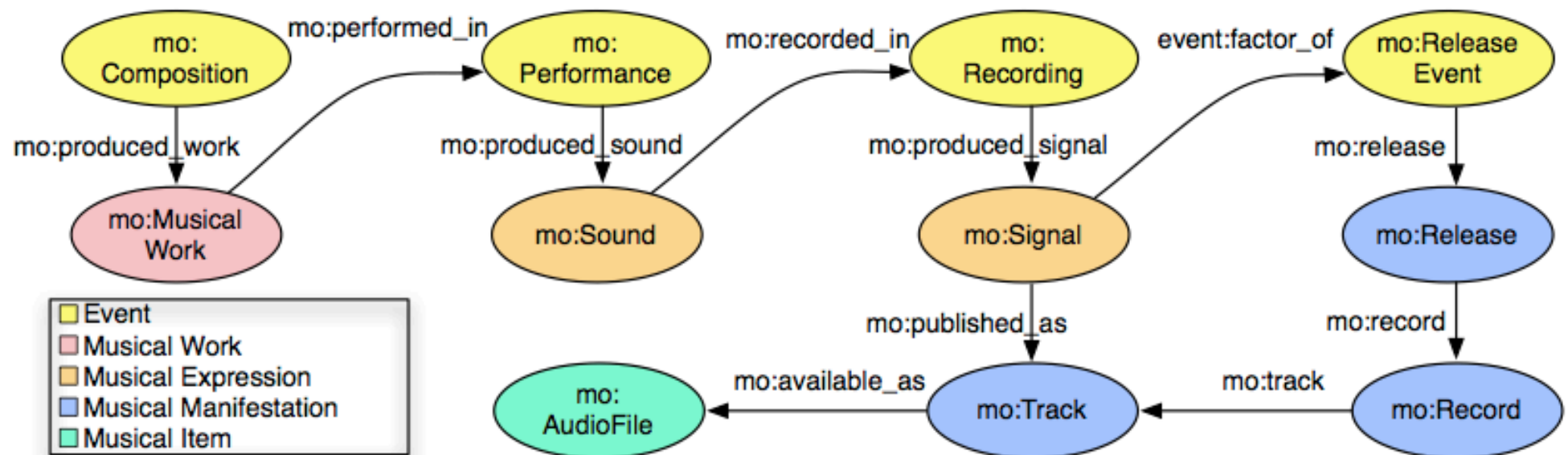
The Music Ontology

- A case study using the Music Ontology:
- The Music Ontology is a core ontology describing the music domain.
- It extends FRBR to describe musical concepts.
- It relies on the Event and Timeline Ontologies to describe the workflow of producing musical (intellectual) works.



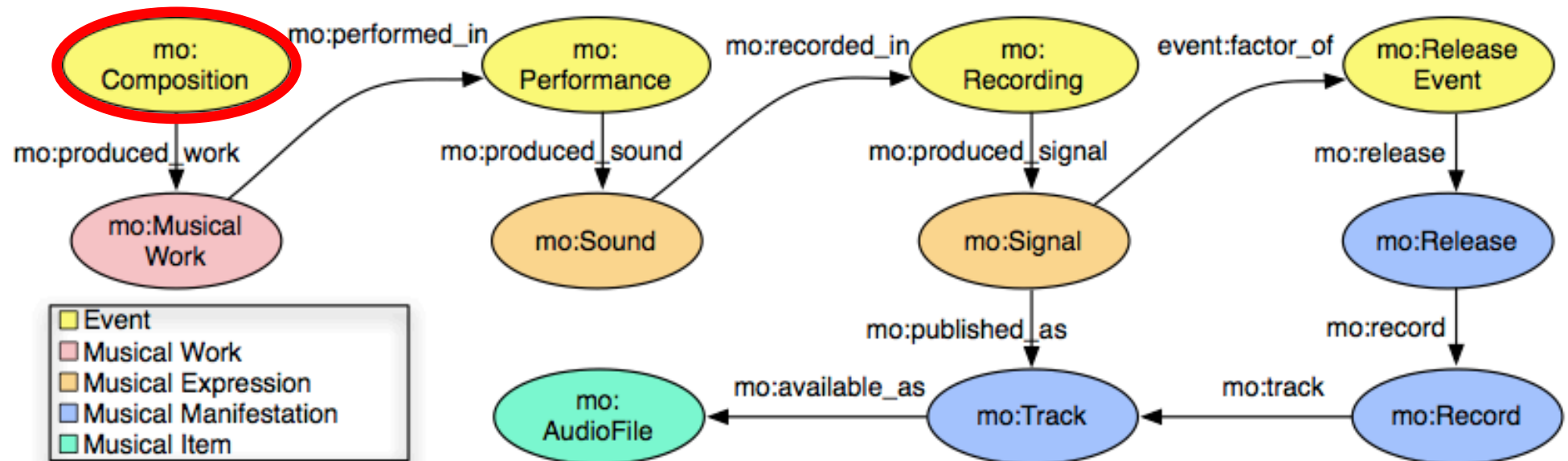
The Music Ontology

- A case study using the Music Ontology:
- Now we can describe the events that allow musical works to be performed, producing a sound,
- a sound recorded, producing a signal,
- a signal released on a CD, which may become available as a file on my computer.



The Music Ontology

- A case study using the Music Ontology:
- Now we can describe the events that allow musical works to be performed, producing a sound,
- a sound recorded, producing a signal,
- a signal released on a CD, which may become available as a file on my computer.



The Music Ontology

- A case study using the Music Ontology:
- A composition event of Bach's "Kunst der Fuge".

Composition event

```
bach:kdfcomposition a mo:Composition;  
    dc:title "The composition event, when Bach composed  
the art of the fugue";  
    mo:composer bach:bach;  
    event:time bach:comptime;  
    mo:produced_work bach:kunstderfuge;  
    event:product bach:kunstderfugescore .
```

The Music Ontology

- A case study using the Music Ontology:
- A composition event of Bach's "Kunst der Fuge".

Composition event

```
bach:kdfcomposition a mo:Composition;  
    dc:title "The composition event, when Bach composed  
the art of the fugue";  
    mo:composer bach:bach;  
    event:time bach:comptime;  
    mo:produced_work bach:kunstderfuge;  
    event:product bach:kunstderfugescore .
```

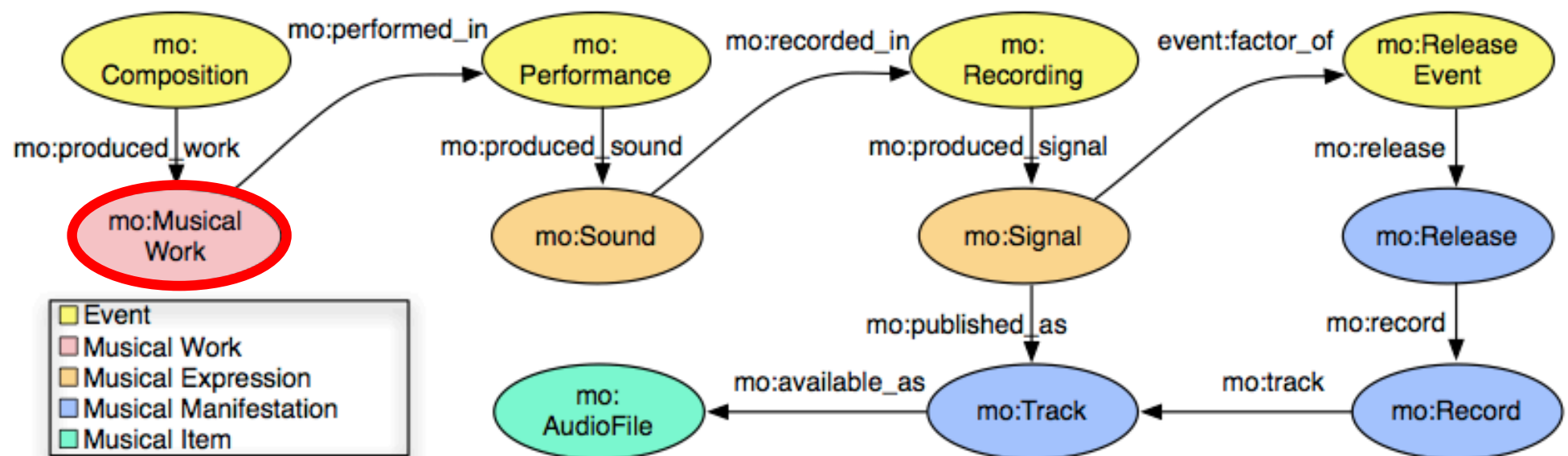
The composition event occurred between 1742 and June 1749

```
bach:comptime a timeline:Interval;  
    timeline:during <http://placetime.com/interval/  
gregorian/1742-01-01T00:00:00Z/P7Y6M> .
```

Source: <http://wiki.musicontology.com>

The Music Ontology

- A case study using the Music Ontology:
- Now we can describe the events that allow musical works to be performed, producing a sound,
- a sound recorded, producing a signal,
- a signal released on a CD, which may become available as a file on my computer.



The Music Ontology

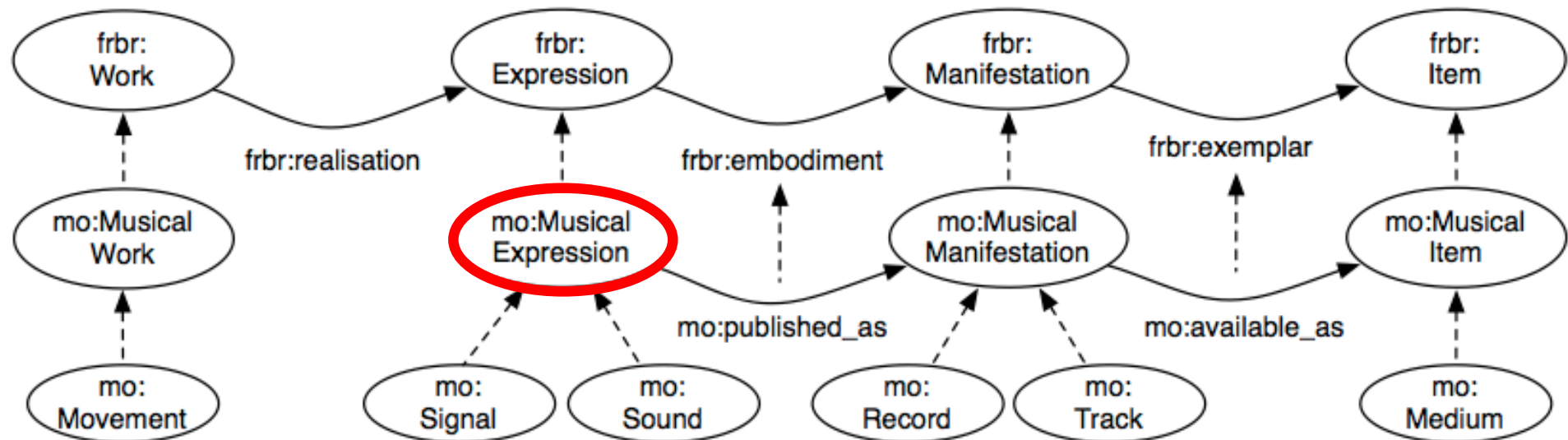
- A case study using the Music Ontology:
- A musical work and its published score

MusicalWork:

**bach:kunstderfuge a mo:MusicalWork ;
dc:title "Die Kunst der Fuge" .**

The Music Ontology

- A case study using the Music Ontology:
- Score is just another expression.
- What would be a manifestation?
- What would be an item?



The Music Ontology

- A case study using the Music Ontology:
- A musical work and its published score

MusicalWork:

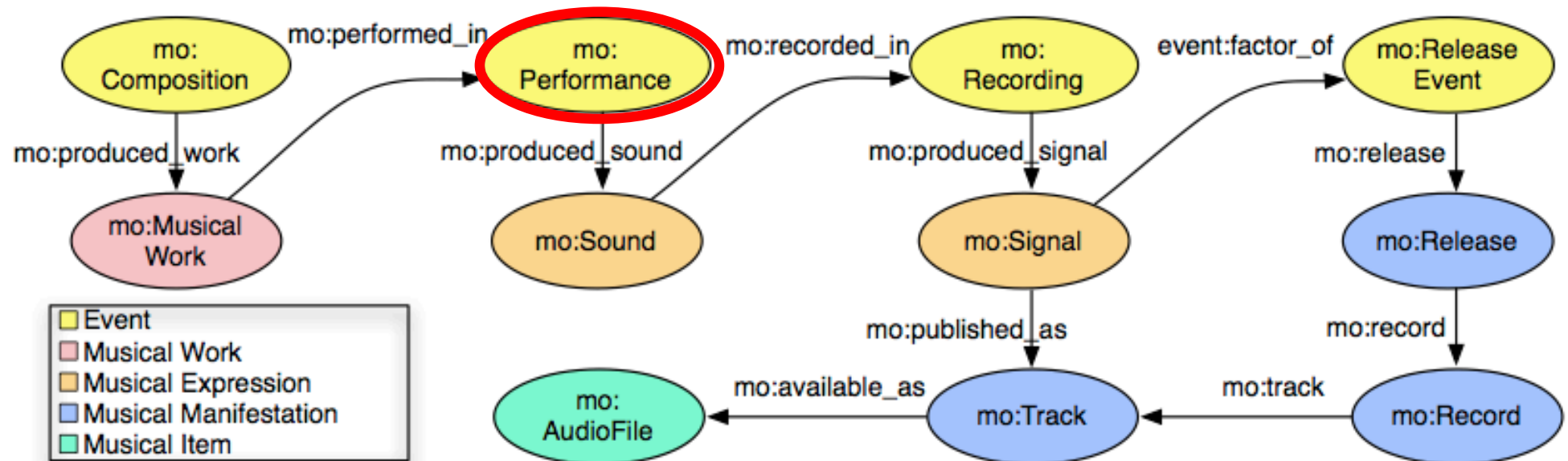
bach:kunstderfuge a mo:MusicalWork ;
dc:title "**Die Kunst der Fuge**" .

A related expression: The composer's score (this is an information object not the actual piece of paper).

bach:kunstderfugescore a mo:Score;
dc:title "**Die Kunst der Fuge, composer's score**";
mo:published_as bach:firstpub .

The Music Ontology

- A case study using the Music Ontology:
- Now we can describe the events that allow musical works to be performed, producing a sound,
- a sound recorded, producing a signal,
- a signal released on a CD, which may become available as a file on my computer.



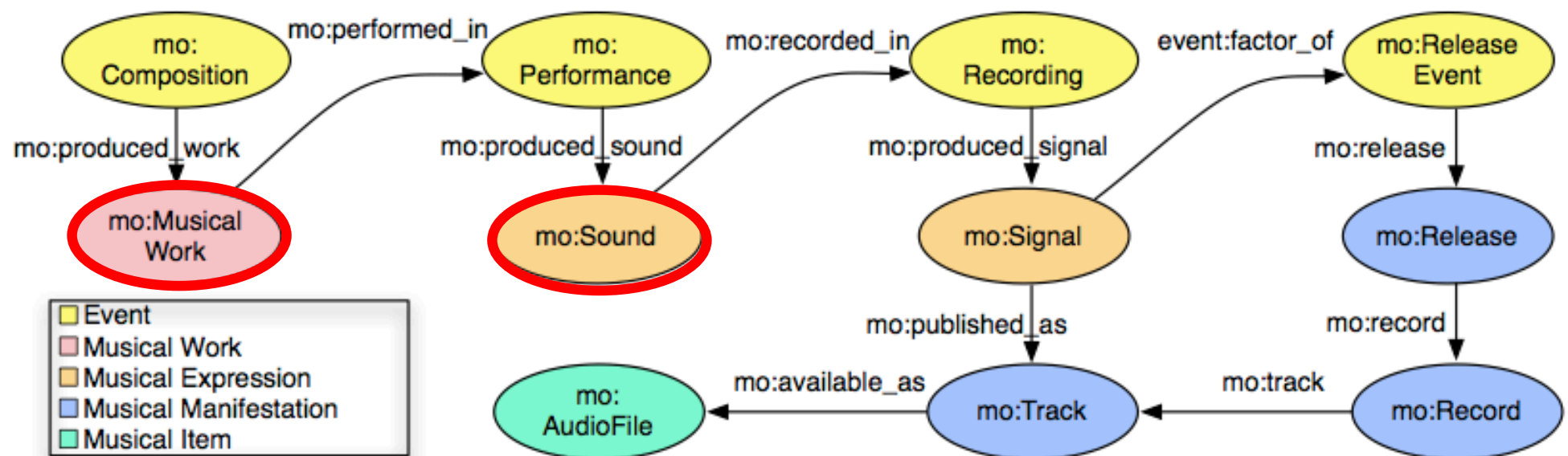
The Music Ontology

- A case study using the Music Ontology:
- A performance event by the Emerson Quartet producing a musical expression

bach:emersonperf a mo:Performance;
event:time bach:emersonperftime;
mo:performer bach:emersonquartet;

The Music Ontology

- A case study using the Music Ontology:
- Now we can describe the events that allow musical works to be performed, producing a sound,
- a sound recorded, producing a signal,
- a signal released on a CD, which may become available as a file on my computer.



The Music Ontology

- A case study using the Music Ontology:
- A performance event by the Emerson Quartet producing a musical expression

bach:emersonperf a mo:Performance;
event:time bach:emersonperftime;
mo:performer bach:emersonquartet;

MusicalExpression

mo:produced_sound bach:emersonsound;

MusicalWork

mo:performance_of bach:kunstderfuge .

- **mo:performance_of** is inverse property of **mo:performed_in**.
-

The Music Ontology

- A case study using the Music Ontology:
- A performance event by the Emerson Quartet producing a musical expression

```
bach:emersonperf a mo:Performance;  
    event:time bach:emersonperftime;  
    mo:performer bach:emersonquartet;
```

MusicalExpression

```
    mo:produced_sound bach:emersonsound;
```

MusicalWork

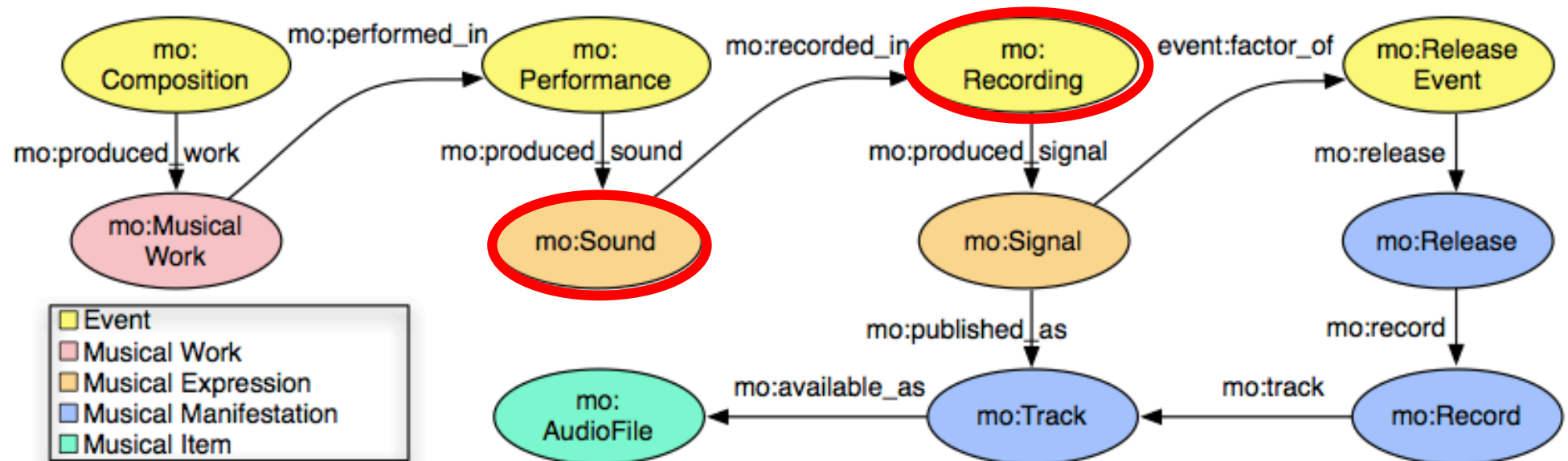
```
    mo:performance_of bach:kunstderfuge .
```

Time during 2003:

```
bach:comptime a timeline:Interval;  
    timeline:during <http://placetime.com/interval/gregorian/2003-01-01T00:00:00Z/P1Y> .
```

The Music Ontology

- A case study using the Music Ontology:
- Now we can describe the events that allow musical works to be performed, producing a sound,
- a sound recorded, producing a signal,
- a signal released on a CD, which may become available as a file on my computer.



The Music Ontology

- A case study using the Music Ontology:
- A recording event produces a musical manifestation (a published record)

MusicalExpressions

bach:emersonsound a mo:Sound.

**bach:emersonrec a mo:Recording;
 mo:recording_of bach:emersonsound;**

. . .

The Music Ontology

- A case study using the Music Ontology:
- A recording event produces a musical manifestation (a published record)

MusicalExpressions

bach:emersonsound a mo:Sound.

bach:emersonrec a mo:Recording;

mo:recording_of bach:emersonsound;

mo:produced_signal [

a mo:Signal;

mo:published_as bach:emerson_record] .

The Music Ontology

- A case study using the Music Ontology:
- A recording event produces a musical manifestation (a published record)

MusicalExpressions

bach:emersonsound a mo:Sound.

bach:emersonrec a mo:Recording;

mo:recording_of bach:emersonsound;

mo:produced_signal [

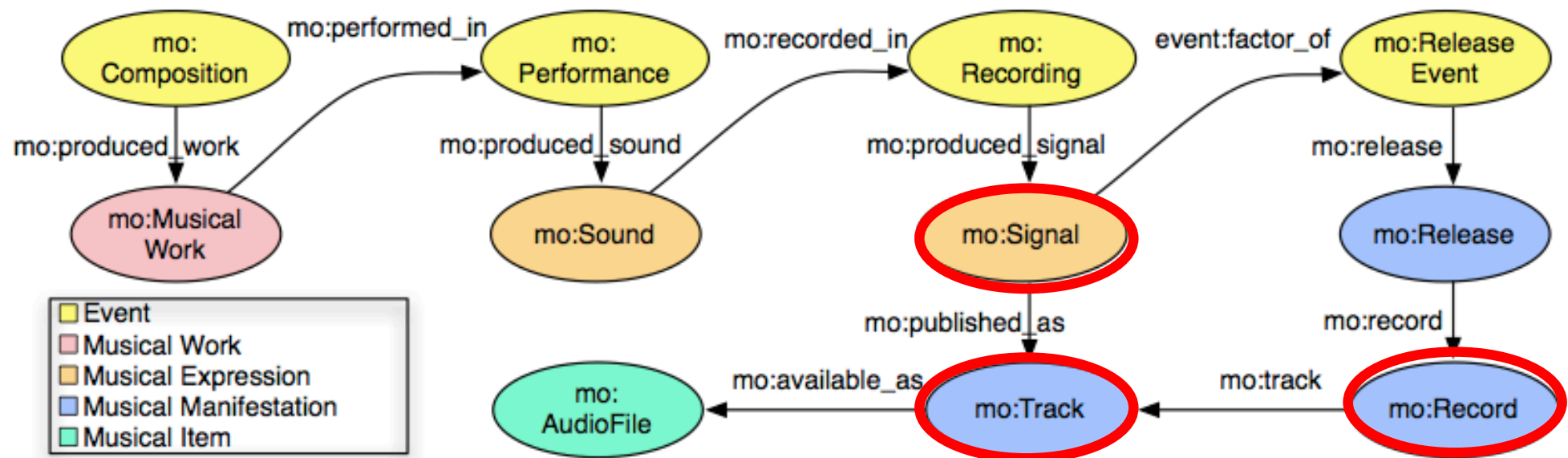
a mo:Signal;

mo:published_as bach:emerson_record] .

- We would typically need a release event, but we can skip that using a shortcut property (mo:published_as) linking a signal to a released record or track.
-

The Music Ontology

- A case study using the Music Ontology:
- Now we can describe the events that allow musical works to be performed, producing a sound,
- a sound recorded, producing a signal,
- a signal released on a CD, which may become available as a file on my computer.



The Music Ontology

- A case study using the Music Ontology:
- A recording event produces a musical manifestation (a published record)

MusicalExpressions

```
bach:emersonsound a mo:Sound.  
bach:emersonrec a mo:Recording;  
  mo:recording_of bach:emersonsound;  
    mo:produced_signal [  
      a mo:Signal;  
      mo:published_as bach:emerson_record ] .
```

MusicalManifestation

```
bach:emerson_record a mo:Record;  
  dc:title "The Art of the Fugue";  
  mo:release_status mo:official;  
  foaf:maker bach:emersonquartet .
```

Provenance and Trust

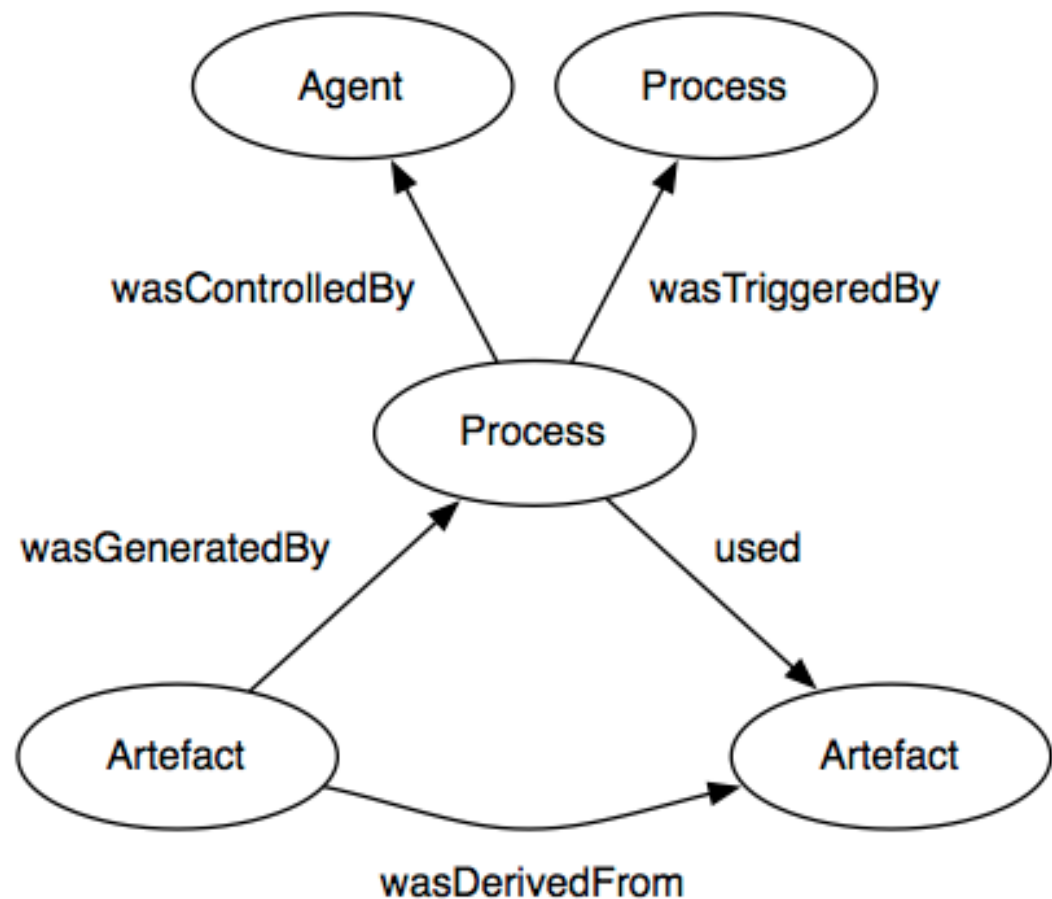
- Origin and quality of information
 - This is a general problem on the Semantic Web
 - Recall the Open World Assumption:
 - if a statement is missing, its truth value is undecided,
 - while in a closed world everything we don't know is assumed to be false.
 - A related problem (but not to be confused with the above), is the origin and quality of statements.
 - We can have conflicting statements about the same thing from different sources on the Semantic Web, and we may want to decide which source to trust.
-

Provenance and Trust

- Origin and quality of information
 - This notion is a very important in the context of multimedia, where content-derived information is often generated by automatic content analysis techniques, which have varying degrees robustness.
 - For instance there are algorithms to determine the musical key of a recording automatically, but different algorithm may produce different results, some of which may be wrong.
-

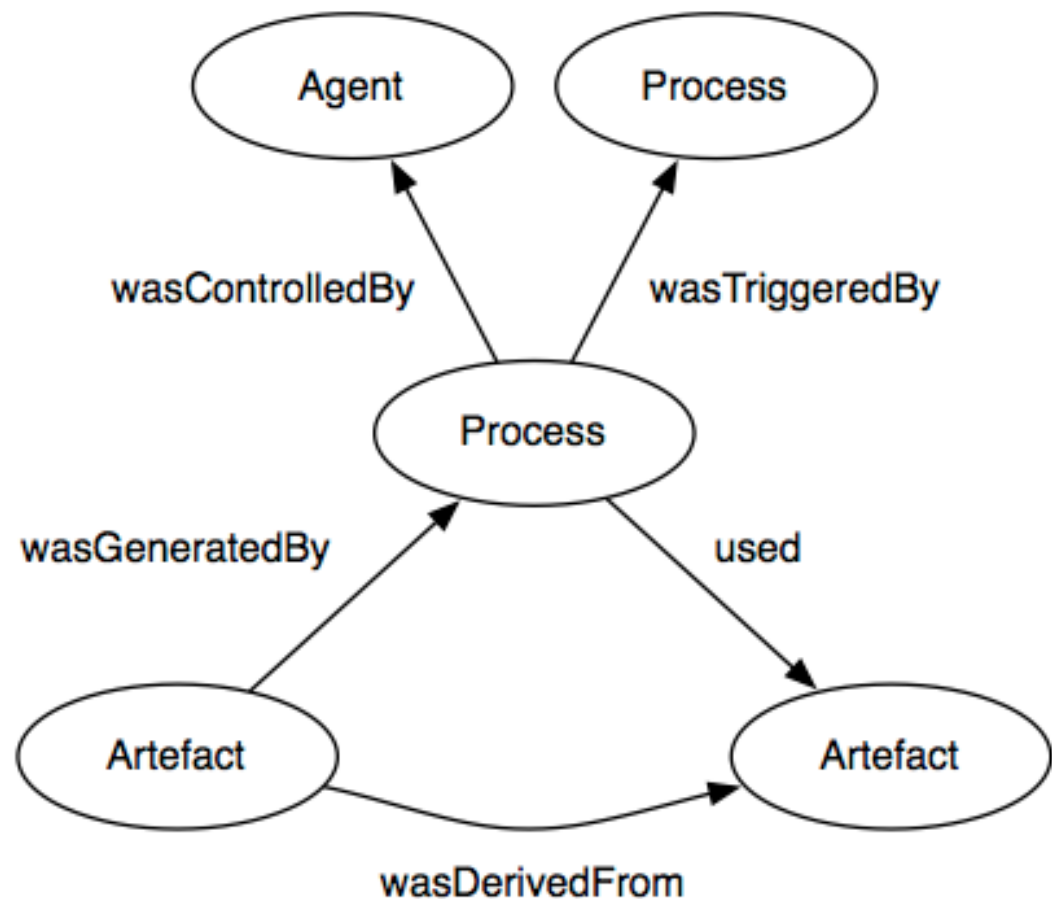
Provenance and Trust

- Open Provenance Model
- An **artefact** is defined as an immutable piece of state which may refer to an actual physical object, a digital representation or some digital data.



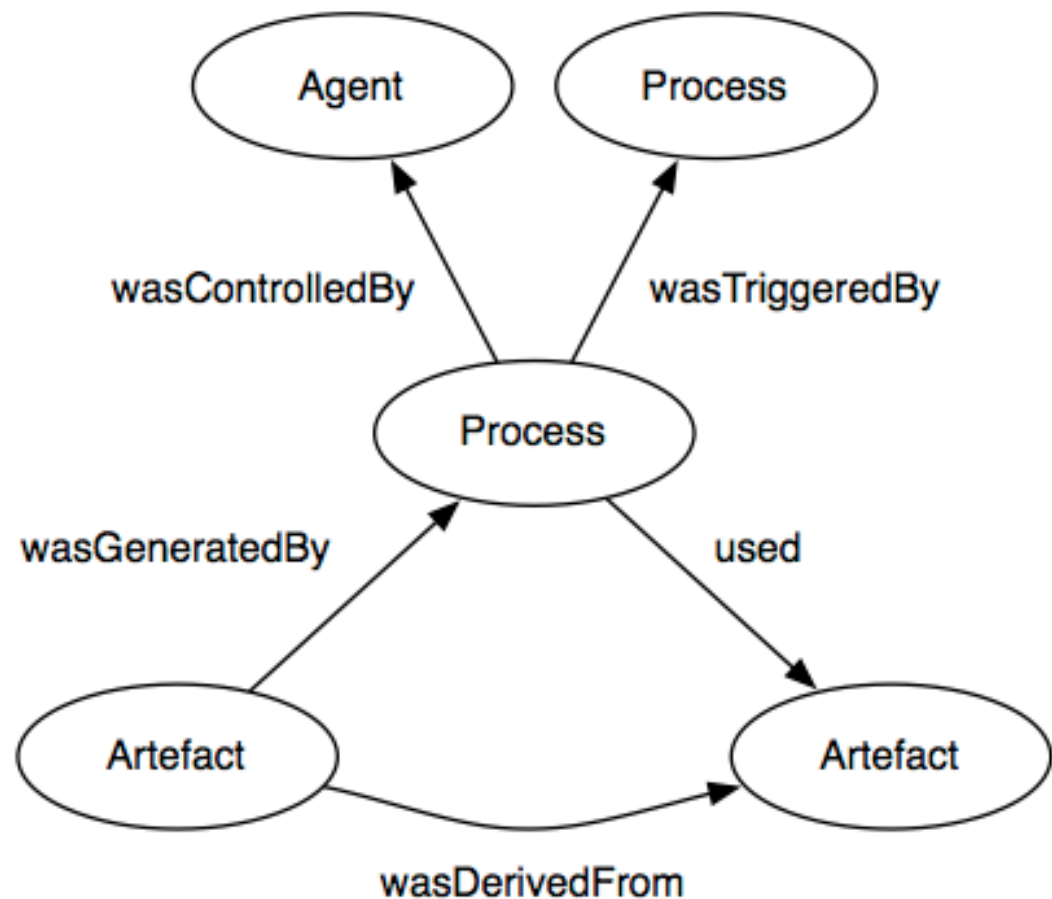
Provenance and Trust

- Open Provenance Model
- A **process** represents an action that creates artefacts, either by acting on an existing artefact or by creating a new one.



Provenance and Trust

- Open Provenance Model
- **Agent** describes an entity involved in a process by enabling or controlling its execution.



Upper ontologies for Multimedia

- The multimedia domain also needs harmonisation
 - Interoperability between multimedia representation schemes has been a problem traditionally
 - One of the first standard in the domain was MPEG7 an XML-based format for representing multimedia data.
 - MPEG7 was re-engineered several times but it has never been applied successfully in a Semantic Web environment.
 - The Core Ontology for Multimedia (COMM) is the latest variant
 - COMM extends DOLCE and reuses concepts from MPEG7
 - This ontology is based in the philosophical foundations of DOLCE and may be used to harmonise more specific domain ontologies.
-

Upper ontologies for Multimedia

- The multimedia domain also needs harmonisation
 - Recall UMBEL (Upper Mapping and Binding Exchange Layer)
 - An “upper ontology” for Linked Data
 - The Music Ontology and the Event Ontology are linked external ontologies within the UMBEL framework
 - Other relevant ontologies include:
 - ABC (Lagoze and Hunter, 2002)
 - CIDOC/CRM (Crofts et al., 2010)
 - MPEG7 and MPEG21 frameworks
 - EBU Core Ontology
-

Conclusions

- Multimedia documents are in abundance on the Web
 - Describing their content is therefore important
 - Describing this content requires talking about:
 - people and their relationships
 - time and temporal entities
 - time-based events
 - workflows, provenance and trust
 - Upper ontologies exist for this domain as well
 - but their best to be used as means for mediating between domain ontologies that may be specific to
 - movies, music, etc...
-