EMBRC reference implementation for provenance of biological material, observations, and data: technical documentation

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Table of contents

1. Scope of this document

This is the technical documentation of the provenance model for biological material, observations, and associated data that was developed by EMBRC as part of Work Package 6 “FAIRification and provenance services” of the EU Horizon project EOSC-Life. In this document we list, describe, and provide recommendations for the classes and properties of the provenance model, and technical details of the implementation of the model in RDF[1] and EML 2.2.0[2]. For a more human-oriented explanation of the model, its background and scope, how it contributes to data FAIRness,, and for worked examples of the implementations of the model, please read the main document (see our GitHub repo).

[1] Resource Description Framework
[2] Ecological Metadata Language

2. The classes of the model

The provenance information is classified into four groups: information about entities, activities, agents, and locations.

- Entity includes objects such as permits and protocols, devices and platforms, samples and software. See Fig. 1 for a diagram and Table 1 for the included classes.
- Agent consists of people and organisations. See Fig. 2 for a diagram and Table 2 for the included classes.
- Location consists of information about the location of an activity. See Fig. 2 for a diagram and Table 2 for the included classes.
- Activity is split into two: physical and digital activities. See Fig. 3 for a diagram and Table 3 for the included classes.

2.1. Entity

Figure 1 shows the class diagram for Entity, and Table 1 lists the classes and describes them.

Table 1 The classes of the model for group Entity

Class	Is a type of…	Description
Entity		An abstract class representing any entity, which is a physical, digital, conceptual, or other kind of thing with some fixed aspects; entities may be real or imaginary
Device	Entity	A class representing devices that are used to carry out an activity: instruments, sensors, containers, also any human-operated devices used in manual observations
SamplingDevice	Device	For types of devices used specifically in field sampling activities
ObservingDevice	Device	For types of devices used specifically to make observations and measurements (in the field or in the lab)
Permit	Entity	A class representing permits, which describe the authorisation to carry out an activity, often needing to be approved by a legal/regulatory entity
Platform	Entity	A class representing platforms, which are entities on/from which a device is deployed (e.g. a ship, a buoy, a CTD carousel, an ROV, etc.)
Protocol	Entity	A class representing protocols, which describe how an activity was done, including the design, methodology, method steps, materials, statistical considerations, etc. Sometimes also called Standard Operating Procedure (SOP)
Sample	Entity	A class representing samples, which consist of biological or environmental material, or any extracts of that material
Software	Entity	A class representing software, being software applications or computer programming source code, but can also be computational workflows, notebooks, and even simple processes such as basic arithmetical calculations

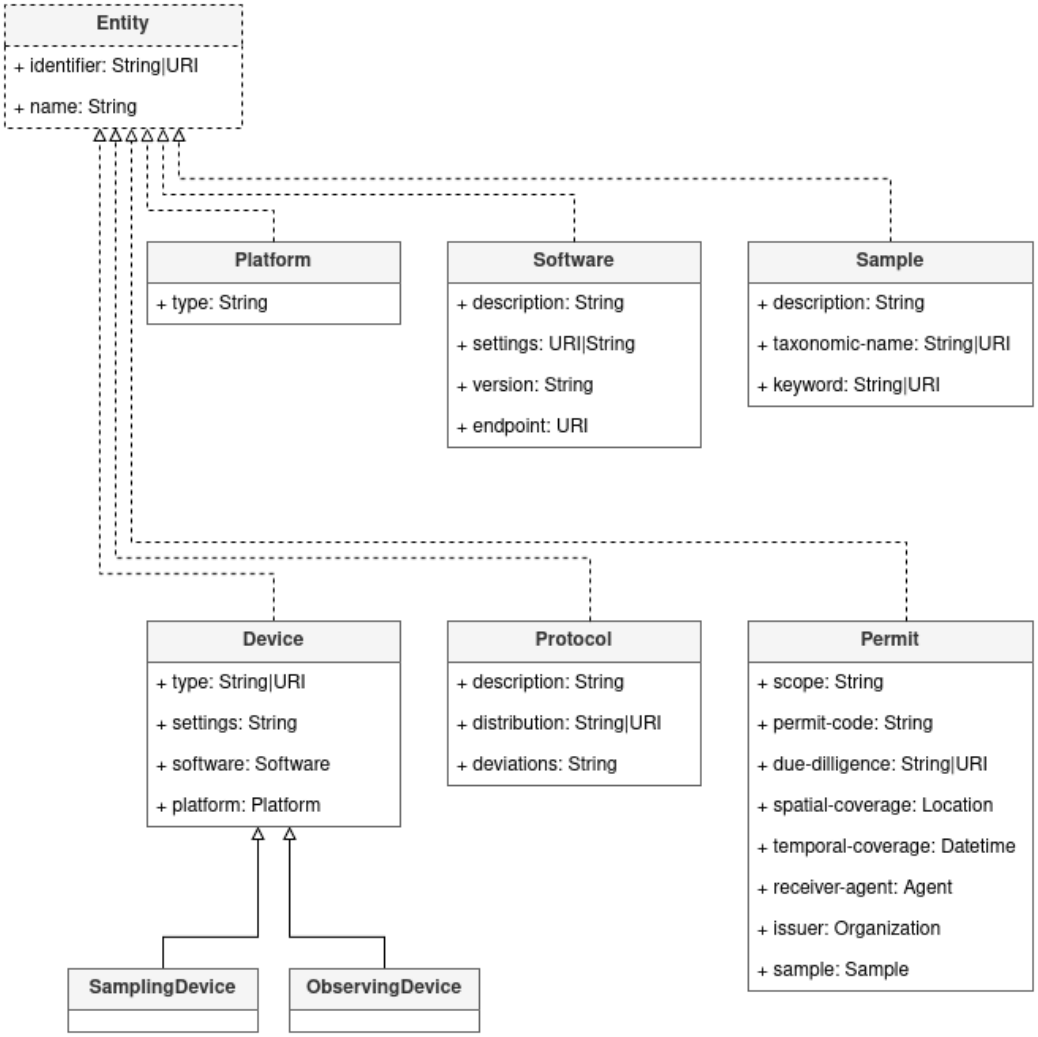

Figure 1 Class diagram of Entity classes.

2.2. Agent and Location

Figure 2 shows the class diagram for Agent and Location, and Table 2 lists the classes and describes them.

Table 2 The classes of the model for groups Agent and Location

Class	Is a type of…	Description
Agent		An abstract class representing the agent responsible for an activity. This can be a Person or Organization
Organization	Agent	A class to represent agents which are social or legal organisations such as a company, project, society, etc
Person	Agent	A class to represent agents which are people
Location		The place at which an activity occurs.

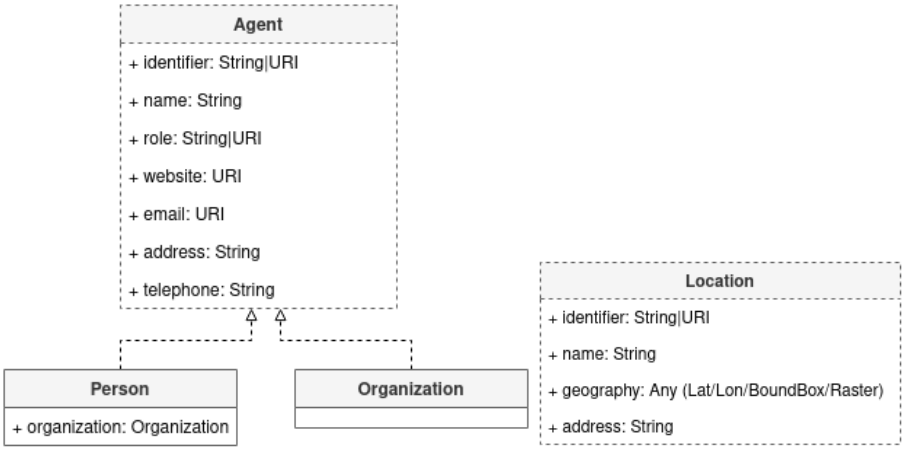

Figure 2 Class diagram of Agent and Location classes.

2.3. Activity

Figure 3 shows the class diagram for Activity, and Table 3 lists the classes and describes them.

Table 3 The classes of the model for group Activity

Class	Is a type of …	Description
Activity		An abstract class representing any activity, which is something that occurs over a period of time, is performed by an agent, and acts upon or with objects/entities
PhysicalActivity	Activity	An abstract class representing any activity that deals with physical material
MaterialAcquiring	PhysicalActivity	A class representing activities where physical material is acquired from an agent (e.g. ordered from a biobank)
Transporting	MaterialAcquiring	A class representing activities where the physical material is moved, posted, shipped
MaterialProcessing	PhysicalActivity	A class representing physical activities where the work done on the physical material transforms that material, e.g. adding preservatives, filtering, centrifuging, extracting, etc
Observing	PhysicalActivity	A class representing physical activities where measurements are made from or of physical material (such as water, organisms, media, laboratory, etc)
Sampling	PhysicalActivity	A class representing acquiring activities where material is collected from the field
Storing	PhysicalActivity	A class representing physical activities where material is retained in a specific location (e.g. storage facility, freezer, etc.), for some length of time
Biobanking	Storing	A class representing storing activities where the physical material is stored in a long-term storage facility (such as a biobank or culture collection facility) specifically to make it available for others to use
DigitalActivity	Activity	An abstract class representing any activity that has a digital nature
DataAcquiring	DigitalActivity	A class representing digital activities where the digital objects are obtained from another digital source, e.g. an online catalogue, a

		colleague's spreadsheet
DataProcessing	DigitalActivity	A class representing digital activities where the digital objects are processed; 'processing' can range from simple calculations to complete workflows

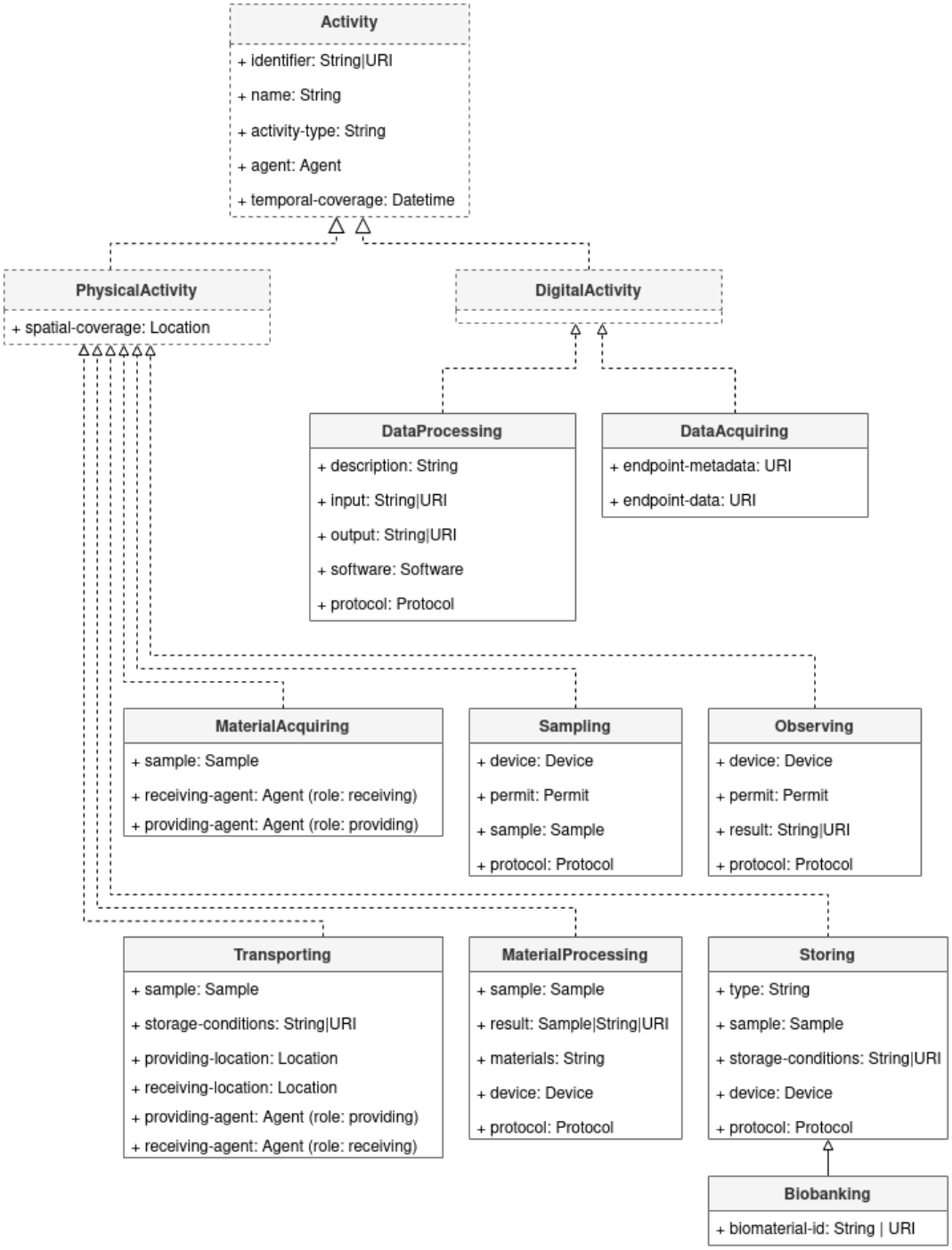

Figure 3 Class diagram of Activity classes.

3. Properties of the classes

The properties of the classes that are listed in Tables 1–3, and the recommended data types to use as values for those properties, can be seen in Figs. 1–3 and are tabulated in Tables 2–4 (recommended data types to use and descriptions).

Note that some of the properties are themselves classes of our model as listed in Tables 1–3, e.g. “spatial-coverage” is a property of a “Sampling” activity; and points to an entity that is of class “Location”, so should be described following the properties of the class “Location”.

3.1. Entity

Tables 4a–g list the properties, data type recommendations, and description for the classes of Entity.

Table 4a Properties of Entity

Property	Recommended data type	Description
identifier	string, URI	An identifier of the entity, ideally being a URL/URI (a web address), but also to include other identifiers (URM, UUID), or a locally-assigned (e.g. lab or project) ID)
name	string	The name of the entity, to provide human-understandability to the identifier, or to be used where no identifier can be assigned

Table 4b Properties of Device, ObservingDevice, and SamplingDevice, which are in addition to those inherited from the Entity class (Table 4a)

Property	Recommended data type	Description
type	string, URI	The type of device, given as a string or a URI to a term from a vocabulary
settings	string, URI	The settings on the device that were relevant/of importance during the activity. Can be text that contains the settings, a URI or string identifying a file with those settings
software	Software (class)	A reference to the software that is used by the device. This property points to an entity that is of the class Software
platform	Platform (class) (class)	The platform on which the device is mounted or hosted. This property points to an entity that is of the class Platform

Table 4c Properties of Permit which are in addition to those inherited from the Entity class (Table 4a)

Property	Recommended data types	Description
scope	string	A description of the (legal) scope of the permit, e.g. the type of material to be collected, any conditions, etc.
spatial-coverage	Location (class)	The geographical area covered by the permit. This property points to an entity that is of the class Location
temporal-coverage	dateTime, date	The date or date range allowed by the permit

permit-code	string	The code given to the permit by the issuer. For example, in the case of ABS permits, this would be the 'Internationally-Recognised Certificate of Compliance'.
due-diligence	string, URI	A description of due diligence, where that information is required by the permit issuer. Can be a string or a URI to a copy of the due diligence email/screenshot/PDF etc
receiver-agent	Agent (class)	The agent that was granted the permit. This property points to an entity that is of the class Agent
issuer	Organization (class)	The agent that has authorised the permit. This property points to an entity that is of the class Organization
sample	Sample (class)	The sample associated with this permit. This should be limited to the sample (or samples) that is the subject of the dataset being described; while the full range of samples (material) covered by the ABS Permit could be broader than this. This property points to an entity that is of the class Sample

Table 4d Properties of Platform, which are in addition to those inherited from the Entity class (Table 4a)

Property	Recommended data types	Description
type	string, URI	The type of platform, given as a string or a URI to a term from a vocabulary

Table 4e Properties of Protocol, which are in addition to those inherited from the Entity class (Table 4a)

Property	Recommended data types	Description
description	string	A description of the protocol: short where the protocol is provided via distribution, otherwise an actual description of the methodology, i.e. the steps followed
distribution	URI, string	A description of where the protocol can be found and/or accessed, preferably a URI but a name of a file included in the dataset is also acceptable
deviations	string	A description of any deviations that occurred from the protocol

Table 4f Properties of Sample, which are in addition to those inherited from the Entity class (Table 4a)

Property	Recommended data types	Description
description	string	A description of the sample
taxonomic-name	string, URI	Any taxonomic names that are associated with the sample; depending on how this is implemented, it can be a string (taxon name), URI (taxon-ID), and can include the taxon-rank, and should include the name of the taxonomic authority if not provided already as a URI
keyword	URI, string	Any keywords useful for describing the sample e.g. body part, processed level (e.g. unprocessed, blended and filtered), type of sample (e.g. ENVO term; particularly if the sample is not of a definable taxonomic type), etc

Table 4g Properties of Software, which are in addition to those inherited from the Entity class (Table 4a)

Property	Recommended data types	Description
description	string	A description of the software application / source code
settings	string, URI	The settings of the software that are of relevance to the use made of that software in the particular work being described. Can be text that contains the settings, or a URI or string identifying a file with those settings
version	string	A version of the software application / source code. Can be a number, a date, etc
endpoint	URI	A URI pointing to the software. Depending on the type of software, this can be for software download or (direct) software use

3.2. Agent and Location

Tables 5a–c list the properties, recommendations and description for the classes of Agent, Persons, Organization, and Location.

Table 5a Properties of Agent and Organization

Property	Recommended data types	Description
identifier	string, URI	An identifier of the agent. We strongly recommend using ORCIDs for people and ROR/EDMO identifiers for Organizations
name	string	The name of the agent (actual name or job title)
role	string	The role of the agent
website	URI	A website of the agent, e.g an organisational or a personal website
email	string	The email address of the agent
address	string	The address of the agent
telephone	number, string	A telephone number of the agent (ideally full international code)

Table 5b Properties of Person which are in addition to those inherited from the Agent class (Table 5a)

Property	Recommended data type	Description
organization	Organization (class)	The organisation that the person is affiliated with. This property points to an entity that is of the class Organization

Table 5c Properties of Location

Property	Recommended data type	Description
identifier	URI, string	An identifier of the location, being a URI (e.g a Marine Region URI) or a PID (e.g. the MarineRegion MRGID number)
name	string	A name for the location, especially to use where an identifier does not exist
geography	number, string, URI	The geography of the location, e.g. geographic coordinates (latitude, longitude), a bounding box

address	string	The postal address of the location

3.3. Activity

Tables 6a–k list the properties, recommendations and description for the classes of Activity.

Table 6a Properties of Activity and DigitalActivity

Property	Recommended data types	Description
identifier	string, URI	An identifier for the activity, e.g. which can be used from elsewhere (within the metadata record or from other metadata records) to refer to that activity
name	string	The name of the activity, to provide human-understandability to the identifier, or to be used where no identifier can be assigned and to provide some context for the activity
activity-type	string	The type of activity carried out (recommended activity type names are those are of the classes linked to Activity, e.g. “sampling”)
agent	Agent (class)	The agent that is associated with the activity. This property points to an entity that is of the class Agent
temporal-coverage	date range, date	The date or date range during which the activity took place

Table 6b Properties of PhysicalActivity which are in addition to those inherited from Activity (Table 6a)

Property	Recommended data types	Description
spatial-coverage	Location (class)	The location where the physical activity took place. This property points to an entity that is of the class Location

Table 6c Properties of the Transporting activity which are in addition to those inherited from PhysicalActivity (Table 6b)

Property	Recommended data types	Description
sample	Sample (class)	The sample that is transported. This property points to an entity that is of the class Sample
providing-location	Location (class)	The location from where the sample was transported. This property points to an entity that is of class Location
receiving-location	Location (class)	The location to where the material was transported. This property points to an entity that is of class Location
providing-agent	Agent (class)	The agent that provides the material being transported. Organisational as well as personal information should be provided. This property points to an entity that is of class Agent
receiving-agent	Agent (class)	The agent that receives the material being transported. Organisational as well as personal information should be provided. This property points to an entity that is of class Agent
storage-conditions	string, number	A description of the storage conditions during the transporting activity

Table 6d Properties of the MaterialAcquiring activity which are in addition to those inherited from PhysicalActivity (Table 6d)

Property	Recommended data types	Description
sample	Sample (class)	The sample that is acquired (i.e. which changes ownership). Ideally the identifier used by the providing organisation should be used (e.g. a biobank ID). This property points to an entity that is of class Sample
providing-agent	Agent (class)	The agent that had (owned) the material that was acquired. This property points to an entity that is of class Agent
receiving-agent	Agent (class)	The agent that receives (i.e. requested/ordered) the material that was acquired. This property points to an entity that is of class Agent

Table 6e Properties of the MaterialProcessing activity which are in addition to those inherited from PhysicalActivity (Table 6b)

Property	Recommended data types	Description
sample	Sample (class)	The sample that is processed. This property points to an entity that is of the class Sample
result	Sample (class); or URI, string	The resulting entity that is generated from the sample during the processing activity. This entity can either be physical –- a sample (instance of the Sample class) – or digital – a file or dataset (instance of a class representing digital results, such as DigitalDocument, Dataset, etc.).
materials	string	A description of the materials that were used in the processing activity (e.g. chemicals, etc.)
device	Device (class)	The device that was used in the processing activity. This property points to an entity that is of the class Device
protocol	Protocol (class)	A protocol or (standard) operating procedure that is associated with the activity. This property points to an entity that is of the class Protocol

A comment on the property “result” in MaterialProcessing. Normally this would be a sample, i.e. physical material. However, it is common that a physical sample goes into an instrument and digital data comes out. Hence: “result” can be of class Sample *or* can be a digital object which can be described as a URI (e.g. the DOI of the published dataset) or a string (e.g. the name of this file in the data package, or a description of the data that is produced).

Table 6f Properties of the Observing activity which are in addition to those inherited from PhysicalActivity (Table 6b)

Property	Recommended data types	Description
device	ObservingDevice (class)	The device used to carry out the observing activity This property points to an entity that is of the class ObservingDevice
protocol	Protocol (class)	A protocol or (standard) operating procedure that is associated with the activity. This property points to an entity that is of the class Protocol
permit	Permit (class)	A permit that was used in relation to the observing activity. This property points to an entity that is of the class Permit
result	URI, string	The result of the observing activity (e.g. a measured parameter, occurrences, etc)

Table 6g Properties of the Sampling activity which are in addition to those inherited from PhysicalActivity (Table 6b)

Property	Recommended data types	Description
device	SamplingDevice (class)	The device used to carry out the observing activity This property points to an entity that is of the class SamplingDevice
protocol	Protocol (class)	A protocol or (standard) operating procedure that is associated with the activity. This property points to an entity that is of the class Protocol
permit	Permit (class)	A permit that was used in relation to the sampling activity. This property points to an entity that is of the class Permit
result	Sample (class)	The sample that resulted from the sampling activity. This property points to an entity that is of the class Sample

Table 6h Properties of the Storing activity which are in addition to those inherited from PhysicalActivity (Table 6b)

Property	Recommended data types	Description
type	string	The type of storing activity (e.g. long term, short term, biobanking, etc.). Useful for context
sample	Sample (class)	The sample that was stored in the storing activity. This property points to an entity that is of the class Sample
protocol	Protocol (class)	A protocol or (standard) operating procedure that is associated with the activity, where that is more detailed that can be provided by storage-conditions alone. This property points to an entity that is of the class Protocol
storage-conditions	string, number	A description of the storage conditions of the storing activity
device	Device (class)	The device that was used for storing the sample. This property points to an entity that is of the class Device

Table 6i Properties of the Biobanking activity which are in addition to those inherited from Storing (Table 6h)

Property	Recommended data types	Description
biomaterial-id	string	The biosample ID of the material that was stored in the storing activity, as is assigned by the biobanking facility from where the material was obtained

Table 6j Properties of the DataAcquiring activity which are in addition to those inherited from DigitalActivity (Table 6a)

Property	Recommended data types	Description
endpoint-metadata	URI	A link to the metadata description of the data acquired
endpoint-data	URI	The entrypoint / link to access the data

Table 6k Properties of the DataProcessing activity which are in addition to those inherited from DigitalActivity (Table 6a)

Property	Recommended data types	Description
description	string	A description of the data processing activity, to provide context
input	string, URI	A reference to or description of the input data
output	string, URI	A reference to or description of the output data
software	Software (class)	The software used during the data processing activity. To be used whenever software is employed. This property points to an entity that is of the class Software.
protocol	Protocol (class)	The protocol used during the data processing activity. To be used either when software is not employed or if post-software processing is also done, e.g. spreadsheet filtering, manual computations, comparisons, etc. This property points to an entity that is of the class Protocol.

4. Implementations

Following are two examples of how to implement the provenance model: one in RDF and the other in XML, based on the EML 2.2.0 schema.

4.1. RDF

For the reference implementation of our provenance model in RDF, we have based ourselves on established W3C standards such as PROV-DM[3], Dublin Core, schema.org, and the Semantic Sensor Network (SSN/SOSA[4]). Rather than creating new types or a new ontology, we defined our classes and properties (i.e. our agnostic information groups) from these standards. These definitions are shown in Figures 4–7 below, and are tabulated in Tables 7–10 (the classes) and 11–14 (their properties).

The main documentation (see our GitHub repo) includes descriptions of a set of example datasets, along with provenance metadata in text, JSON-LD (RDF), and EML (XML). These examples are available in our GitHub repository.

[3] https://www.w3.org/TR/prov-dm/
[4] https://www.w3.org/TR/vocab-ssn/

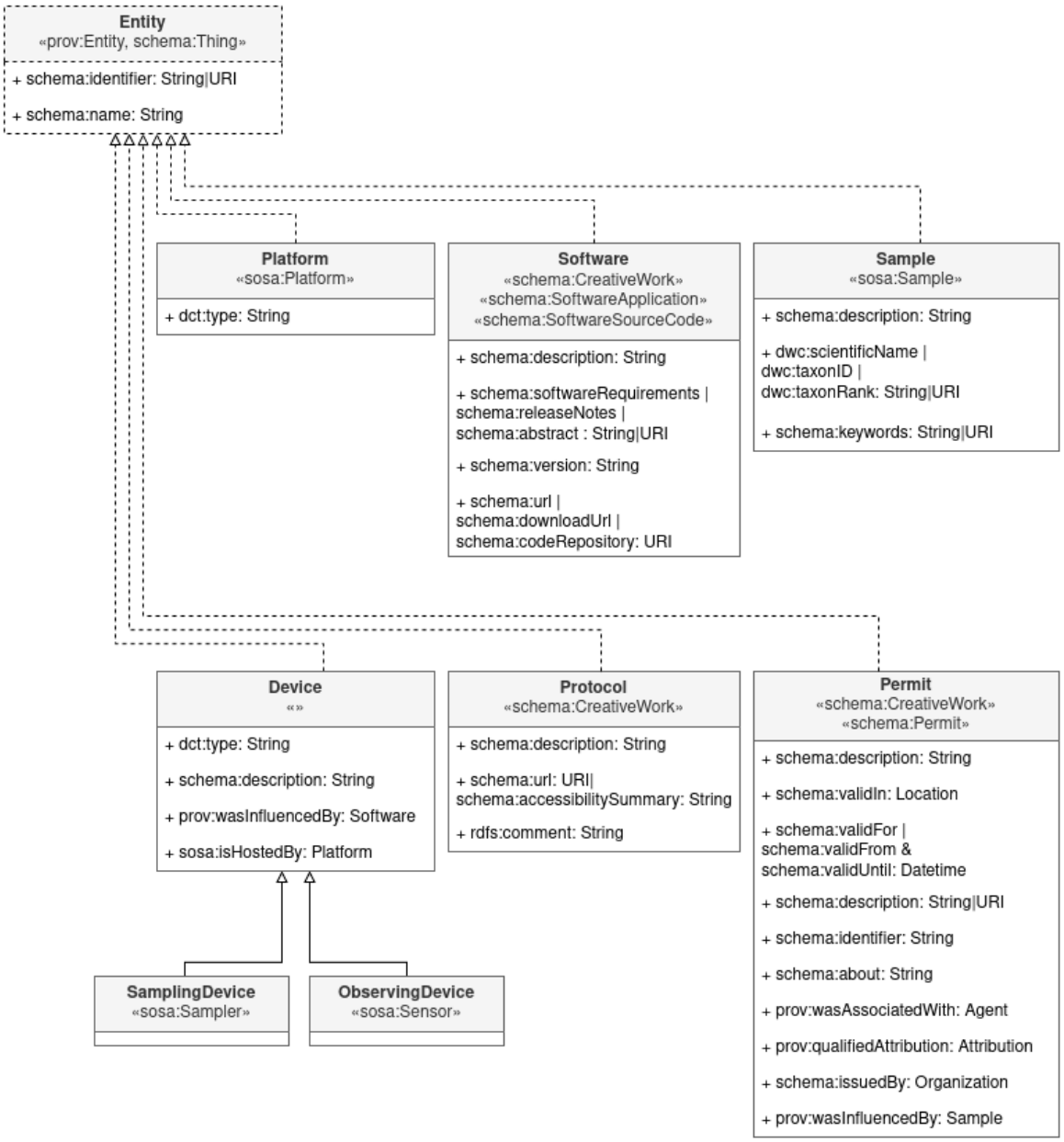

Figure 4 Class diagram of the RDF implementation of Entity classes and their properties.

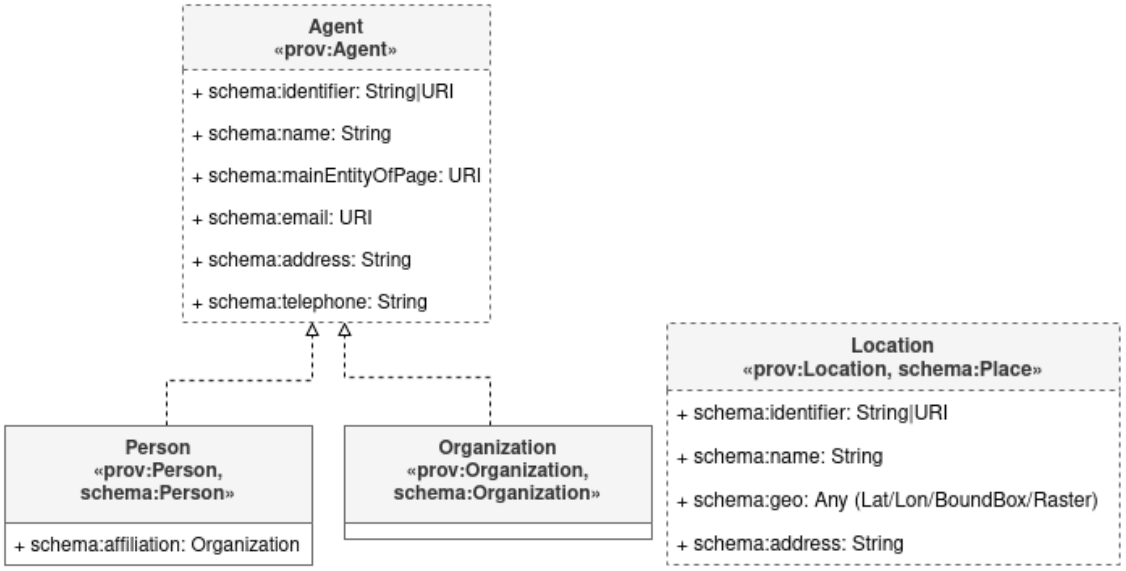

Figure 5 Class diagram of the RDF implementation of Agent and Location classes and their properties.

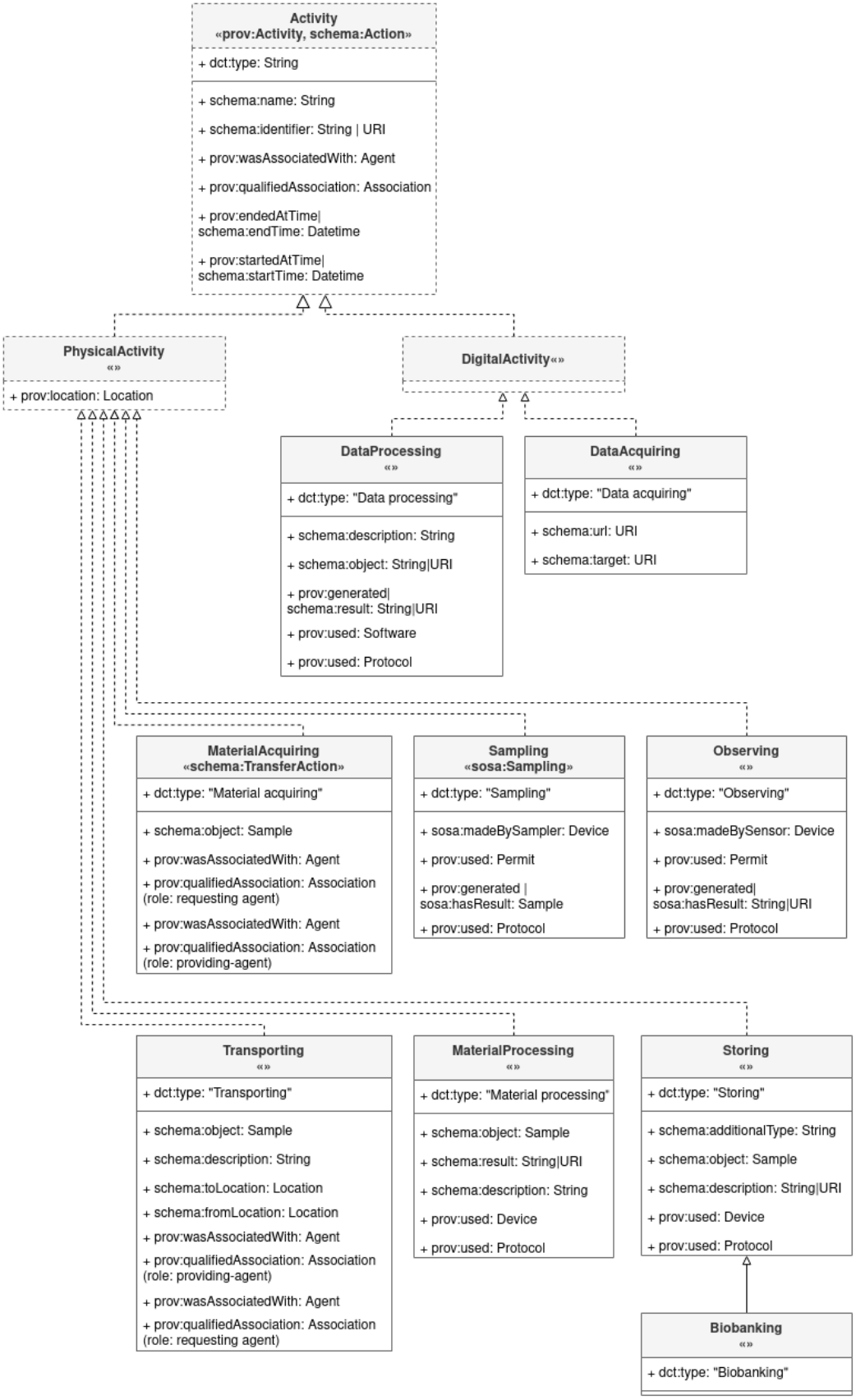

Figure 6 Class diagram of the RDF implementation of Activity classes and their properties.

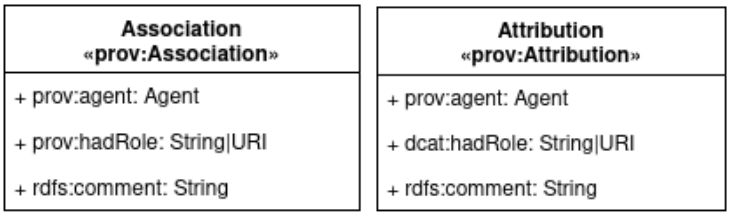

Figure 7 Class diagram of the RDF implementation of the Association and Attribution classes, which represent the role of an Agent in an Activity and an Entity, respectively.

4.1.1. Classes

Tables 7–10 describe the RDF implementation of the classes Entity, Agent, Location, and Activity. Additionally, in the RDF implementation, the property "role", which is part of Agent in the agnostic model, is accommodated via classes that are extra to those in the agnostic model, as described in Table 10 (and then in the properties tables in Sec. 4.1.2 below).

Table 7 RDF implementation of the classes of the model for group Entity

Class	Is a type of …	RDF Implementation
Entity		prov:Entity, schema:Thing
Device	Entity	prov:Entity, schema:Thing
SamplingDevice	Device	prov:Entity, schema:Thing, sosa:Sampler
ObservingDevice	Device	prov:Entity, schema:Thing, sosa:Sensor
Permit	Entity	prov:Entity, schema:Thing, schema:CreativeWork, schema:Permit
Platform	Entity	prov:Entity, schema:Thing, sosa:Platform
Protocol	Entity	prov:Entity, schema:Thing, schema:CreativeWork
Sample	Entity	prov:Entity, schema:Thing, sosa:Sample
Software	Entity	prov:Entity, schema:Thing, schema:creativeWork, schema:SoftwareApplication | schema:SoftwareSourceCode

Table 8 RDF implementation of the classes of the model for groups Agent and Location

Class	Is a type of …	RDF Implementation
Agent		prov:Agent
Organization	Agent	prov:Person, schema:Person
Person	Agent	prov:Organization, schema:Organization
Location		prov:Location, schema:Place

Table 9 RDF implementation of the classes of the model for group Activity

Class	Is a type of …	RDF Implementation
Activity		prov:Activity, schema:Action
PhysicalActivity	Activity	prov:Activity, schema:Action
MaterialAcquiring	PhysicalActivity	prov:Activity, schema:Action, schema:TransferAction ; dct:type “Material acquiring”
Transporting	MaterialAcquiring	prov:Activity, schema:Action | schema:TransferAction ; dct:type “Transporting”
MaterialProcessing	PhysicalActivity	prov:Activity, schema:Action ; dct:type “Material processing”
Observing	PhysicalActivity	prov:Activity, schema:Action ; dct:type “Observing”
Sampling	PhysicalActivity	prov:Activity, schema:Action | sosa:Sampling ; dct:type “Sampling”
Storing	PhysicalActivity	prov:Activity, schema:Action ; dct:type “Storing”
Biobanking	Storing	prov:Activity, schema:Action ; dct:type “Biobanking”
DigitalActivity	Activity	prov:Activity, schema:Action
DataAcquiring	DigitalActivity	prov:Activity, schema:Action ; dct:type “Data acquiring”
DataProcessing	DigitalActivity	prov:Activity, schema:Action ; dct:type “Data processing”

Table 10 RDF implementation of the Association & Attribution classes. These are to specify the role of an Agent in an Activity or Entity: in the agnostic model the role of Agent, but in the RDF implementation it has to be part of Activity or Entity and so should be included in the properties of those classes.

Class	Is a type of …	RDF Implementation
Association	n/a	prov:Association
Attribution	n/a	prov:Attribution

4.1.2. Properties

Tables 11–13 describe the RDF implementation of the properties of the classes of Entity, Agent, Location, and Activity. Additionally, in the RDF implementation, the property “role”, which is part of Agent in the agnostic model, needs to be incorporated within the Entities or Activities, and that is described in the respective tables and Table 14.

Entity

Table 11 a,b RDF implementation of the properties of (**A**, left) Device, ObservingDevice, and SamplingDevice, (**B**, right) Platform

Property	RDF implementation
identifier	schema:identifier
type	dct:type
name	schema:name
settings	schema:description
software	prov:wasInfluencedBy
platform	sosa:isHostedBy

Property	RDF implementation
identifier	schema:identifier
type	dct:type
name	schema:name

Table 11 c,d RDF implementation of the properties of Permit (**C**, left), Protocol (**D**, right)

Property	RDF implementation
name	schema:name
permit-code	schema:identifier
scope	schema:description
spatial-coverage	schema:validIn
temporal-coverage	schema:validFor, schema:validFrom, schema:validUntil | schema:temporalCoverage
due-diligence	schema:about
receiver-agent	prov:wasAssociatedWith
receiver-agent role	prov:qualifiedAttribution
issuer	schema:issuedBy
sample	prov:wasInfluencedBy

Property	RDF implementation
name	schema:name
description	schema:description
description	schema:step
distribution	schema:url
distribution	schema:accessibilitySummary
deviations	rdfs:comment

Table 11 e,f RDF implementation of the properties of Sample (**E**, left), Software (**F**, right)

Property	RDF implementation
name	schema:name
description	schema:description
taxonomic-name	dwc:scientificName. dwc:taxonID, dwc:taxonRank, sosa:isSampleOf, schema:about
keyword	schema:keywords

Property	RDF implementation
name	schema:name
description	schema:description
settings	schema:softwareRequirements, schema:abstract, schema:releaseNotes, …
version	schema:version
endpoint	schema:url, schema:downloadUrl, schema:featureList, schema:codeRepository

Agent and Location

Table 12a, b, c RDF implementation of the properties of (**A**, left) Agent and Organization, (**B**, right top) Person, (**C**, right bottom) Location

Property	RDF implementation
identifier	schema:identifier
name	schema:name
website	schema:mainEntityOfPage
email	schema:email
address	schema:address
telephone	schema:telephone

Property	RDF implementation
organization	schema:affiliation

Property	RDF implementation
identifier	schema:identifier
name	schema:name
geography	schema:geo
address	schema:address

Activity

Table 13 a,b RDF implementation of the properties of (**A**, left) Activity and DigitalActivity, (**B**, right) PhysicalActivity which are in addition to those inherited from Activity

Property	RDF implementation
activity-type	dct:type
name	schema:name
identifier	schema:identifier
agent	prov:wasAssociatedWith
agent-role	prov:qualifiedAssociation
temporal-coverage	schema:endTime|prov:endedAtTime, schema:startTime|prov:startedAtTime

Property	RDF implementation
spatial-coverage	prov:location

Table 13 c,d RDF implementation of the properties of (**C**, left) MaterialAcquiring, which are in addition to those inherited from PhysicalActivity, (**D**, right) Transporting, which are in addition to those inherited from PhysicalActivity

Property	RDF implementation
source	schema:object
storage-conditions	schema:description
receiving-location	schema:toLocation
providing-location	schema:fromLocation
providing-agent	prov:wasAssociatedWith
receiving-agent	prov:wasAssociatedWith
providing-agent role	prov:qualifiedAttribution
receiving-agent role	prov:qualifiedAttribution

Property	RDF implementation
source	schema:object
providing-agent	prov:wasAssociatedWith
receiving-agent	prov:wasAssociatedWith
providing-agent role	prov:qualifiedAttribution
receiving-agent role	prov:qualifiedAttribution

Table 13 e,f RDF implementation of the properties of (**E**, left) MaterialProcessing which are in addition to those inherited from PhysicalActivity, (**F**, right) Observing activity which are in addition to those inherited from PhysicalActivity

Property	RDF implementation
sample	schema:object
result	schema:result
materials	schema:description
device	prov:used
protocol	prov:used

Property	RDF implementation
device	sosa:madeBySensor
protocol	prov:used
permit	prov:used
result	prov:generated, sosa:hasResult

Table 13 g, h RDF implementation of the properties of (**G**, left) Sampling which are in addition to those inherited from PhysicalActivity, (**H**, right) Storing activity which are in addition to those inherited from PhysicalActivity

Property	RDF implementation
device	sosa:madeBySampler
protocol	prov:used
permit	prov:used
result	prov:generated, sosa:hasResult

Property	RDF implementation
type	schema:additionalType
sample	schema:object
protocol	prov:used
storage-conditions	schema:description
device	prov:used

Table 13 i RDF implementation of the properties of Biobanking which are in addition to those inherited from Storing

Property	RDF implementation
biomaterial-id	schema:object

Table 13 j, k RDF implementation of the properties of (**J**, left) DataAcquiring which are in addition to those inherited from DigitalActivity, (**K**, right) DataProcessing which are in addition to those inherited from DigitalActivity

Property	RDF implementation
endpoint-metadata	schema:url
endpoint-data	schema:target

Property	RDF implementation
name	schema:name
description	schema:description
input	schema:object
output	prov:generated
software	prov:used

Role

Table 14 RDF implementation of the properties of Association (**C**, left) and Attribution (**D**, right), which represent the role of an Agent in an Activity and an Entity, respectively

Property	RDF implementation
agent	prov:agent
role	prov:hadRole
comment	rdfs:comment

Property	RDF implementation
agent	prov:agent
role	prov:hadRole
comment	rdfs:comment

4.2. Ecological Metadata Language (EML)

This section will be added in the next release of this document.