Bilbao, Marzo de 2021

ONTOLOGY DOCUMENTATION

Contents

1. Ontological design

This section is going to break down from minor to major detail the design of the ROH ontology network. Starting in section 1 with a high-level diagram, the most important entities will be shown. Then, the main entities modelled are broken down (sections 1.3 to 1.8). Before, the following table shows a summary of the reused ontologies together with their respective user licenses. All reused ontologies have been evaluated for compatibility with their import and extension.

prefix	Ontology names	License	Ontology website
bibo	Bibliographic Ontology	Creative Commons Attribution 1.0 Generic (CC BY 1.0)	http://purl.org/ontology/bibo
foaf	FOAF (Friend of a Friend) Vocabulary Specification	Creative Commons Attribution License 1.0	http://xmlns.com/foaf/0.1
geonames	Geonames ontology	Creative Commons Attribution License 3.0	http://www.geonames.org/ontology#
obo	Open Biological and Biomedical Ontology (OBO)	Creative Commons Attribution License 4.0	http://purl.obolibrary.org/obo/
obo-bfo	OBO Foundry, Basic Formal Ontology	Creative Commons Attribution License 4.0	http://www.obofoundry.org/ontology/bfo.html
obo-ero	OBO Foundry, eagle-i Research Resource Ontology	Creative Commons Attribution License 4.0	https://open.catalyst.harvard.edu/wiki/display/eaglei/Ontology

	(ERO)		
obo-iao	OBO Foundry, Information Artifact Ontology	Creative Commons Attribution License 4.0	https://github.com/information-artifact-ontology/IAO/
obo-ro	OBO Foundry, Relations Ontology	Creative Commons Attribution License 4.0	http://www.obofoundry.org/ontology/ro.html
rdfs	RDF Schema	Creative Commons Attribution License 4.0	http://www.w3.org/2000/01/rdf-schema#
roh	Red de Ontologías Hercules	Creative Commons Attribution License 4.0	http://purl.org/roh
skos	SKOS Simple Knowledge Organization System RDF Schema	Creative Commons Attribution License 4.0	http://www.w3.org/2004/02/skos/core#
terms	DCMI Metadata Terms	Creative Commons Attribution License 4.0	https://www.dublincore.org/specifications/dublin-core/dcmi-terms/
vcard	vCard Ontology - for describing People and Organizations	Creative Commons Attribution License 4.0	https://www.w3.org/2006/vcard/ns#
vivo	VIVO Ontology for Researcher Discovery	Creative Commons Attribution License 4.0	http://vivoweb.org/ontology/core#
oa			

1.1. Conceptual diagram of ontology ROH

Figura 1 shows the main entities modelled in the Hercules Ontology Network (HON in English, ROH-Red de Ontologías Hércules in Spanish). Note that in the diagram, the arrows with a filled tip denote kinship (inheritance) relationships while the arrows that end in a non-filled tip indicate that there is an Object Property relationship between these entities. Finally, the dashed arrows reflect the fact that several entities in ROH have geographic (class `Geonames:Feature`) and temporal (class `vivo:DateTimeInterval`) constraints.

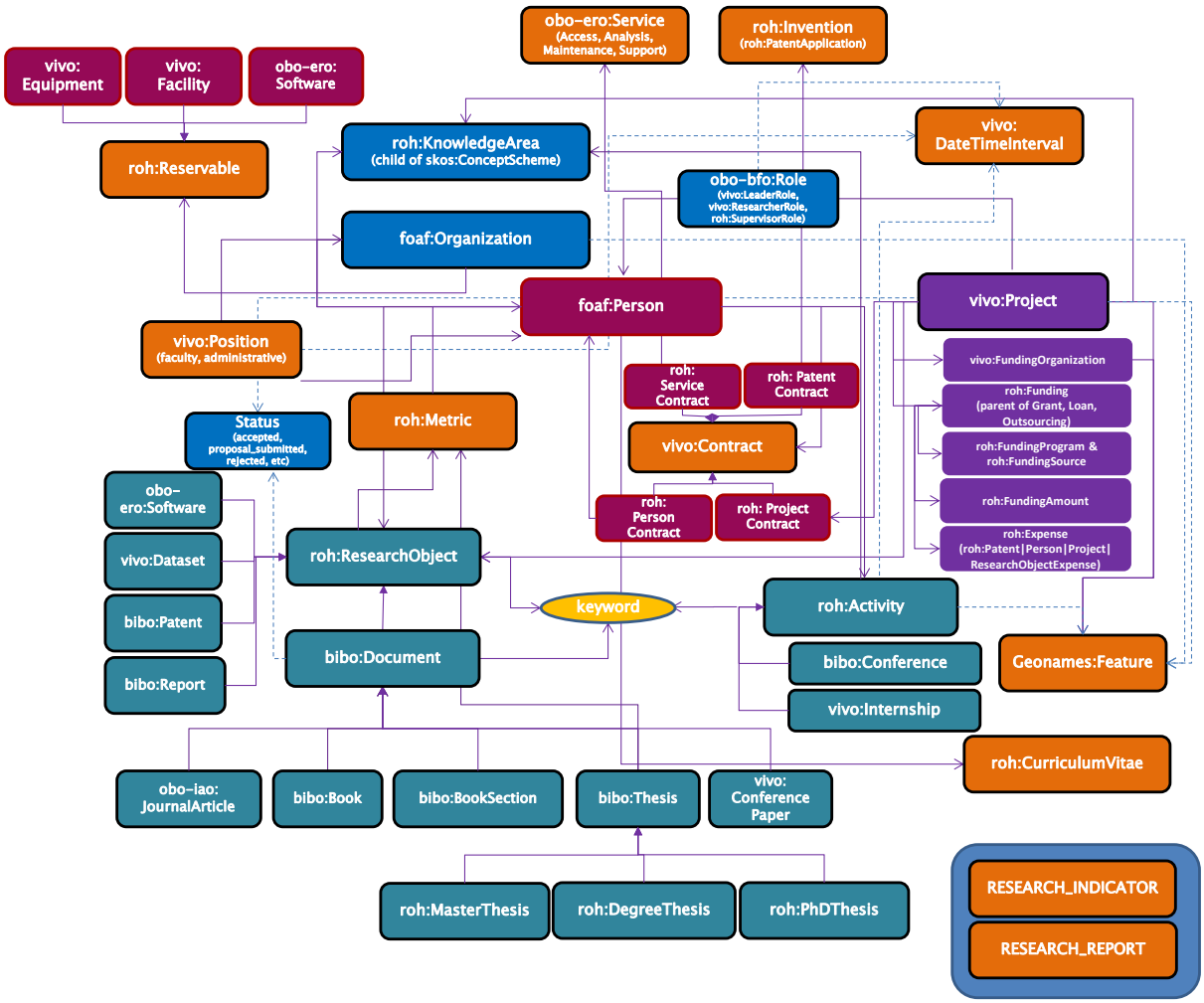

Figura 1. High level diagram of ROH –Red de Ontologías Hércules.

1.2. Modules in ROH network of ontologies

The following table lists all ontologies created, which combine entities defined specifically in our core ontology under prefix roh with those reused from other well-known and extensively adopted ontologies. Notice that ROH network of ontologies is divided into 2 main parts as depicted in the following figure:

- The generic ontology, **core module**, contains the most important entities and properties to model information in the academic domain. It contains the central part of the network of ontologies. It covers the academic domain, being agnostic to the country or the research organization whose information wants to be modelled with.
- A set of **vertical modules** which include, on one hand, specializations of some academic concepts for a given country domain. For instance, the figure Associate Professor in the Spanish academic domain would be encountered in the vertical module `university-HR-es` and is assigned the URI `http://purl.org/roh/university-hr/es#ProfesorTitularDeUniversidad`. On the other hand, these vertical modules, include controlled vocabularies, according to SKOS ontology, for different important areas in the academic domain, namely, geographical locations (`geopolitical`) , knowledge areas (including concepts for `scientific-domains`, `subject-areas` or `unesco-codes`), classification of project types (`project-classification`), resource positions in universities (`university-HR` for Spain, UK or Portugal), controlled vocabulary with all universities in Spain (`university-structure`) or some extensions for the Spanish university system (`extensions-es`).

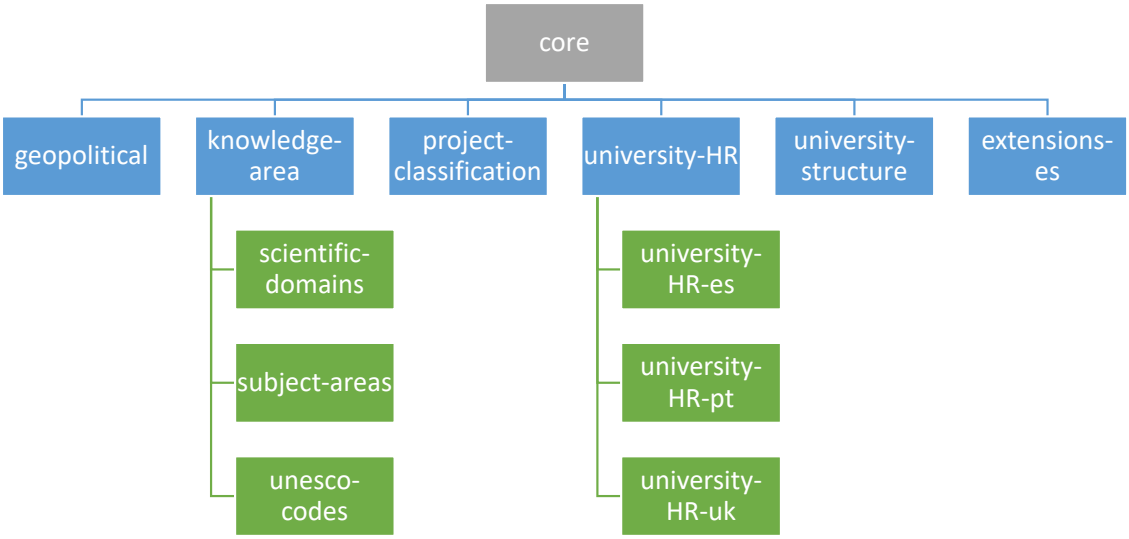

Figura 2. Hierarchical module structure of ROH network of ontologies.

1.3. Entity Project

The main ROH entity is `vivo:Project` (see Figura 3), a new entity defined within ROH. In ROH, a Project models a collaborative activity in business and science that often involves research or design and is carefully planned to achieve a particular goal. Its configuration is inspired by the `swrc:Project` and takes into account the data properties of the `cerif:Project` and `vivo:Project`. It comprises all those properties and adds some new ones, for example, `roh:projectStatus`, `roh:modality` or `roh:title`.

It includes the Data Properties `roh:identifier`, `vivo:abbreviation`, `vivo:description`, `roh:title`, `vivo:freeTextKeyword`, `roh:modality`, `roh:foreseenJustificationDate`, `roh:projectObjective` and `roh:needsEthicalValidation`.

An `vivo:Project` includes a property `roh:hasKnowledgeArea` with allows to associate a project with different instances of knowledge areas, e.g. instances of `skos:Concept` belonging to `roh:UNESCOKnowledgeArea` controlled vocabulary or concept scheme. Besides, it allows a project also to be classified (`roh:hasProjectCategorization`) according the project categories defined in hierarchy defined under the concept scheme `roh:ProjectClassification`, e.g. `http://purl.org/roh/project-classification#Horizon2020`. Likewise a project might be associated to the recruitment of a new human resource, in that case `roh:hasHRClassification` allows to link a project with a `roh:HumenResourceClassification`. A project may go through different stages, i.e. `roh:projectStatus` during its lifetime, e.g. `roh:Open`, `roh:ProposalSubmitted`, `roh:Rejected` or `roh:Closed`.

Besides, an instance of a `vivo:Project` is associated to the following entities through object properties:

- `roh:Activity` is `roh:participatedBy` a project, describes what activities a project participates in.
- `skos:Concept` is linked through `roh:knowledgeAreaOf` to a project, indicating the topics/concepts a project deals with. A project may be classified according to distinct taxonomies (concept schemes) for `roh:ProjectClassification` and `roh:HRClassification` (human resources).

- `roh:Dossier` through relationship `vivo:relates` binds a set of documents, including the proposal, evaluation document, reports and so on with a `vivo:Project`. A dossier is an administrative file collection in which all assets related to a Project are stored, including the Research Proposal, approval documents, viability plans and so on associated to a project are stored.
- `roh:Funding` `roh:supports` a `vivo:Project`, where funding `obo-ro:BFO_0000051` (has part) `roh:FundingAmount`. A `roh:FundingAmount` `roh:grants` `foaf:Organization` and describes the details about the funding associated to a project, in what period and what organization it funds. A `roh:FundingSource` is `roh:promotedBy` a `vivo:FundingProgram` which is `roh:promotedBy` a `vivo:FundingOrganization`. `foaf:Organization`, where different organizations may play different `obo-bfo:Roles` in a project, e.g. `vivo:MemberRole` or `vivo:AdministratorRole`. Notice that the object property `vivo:relates` allows to link a `foaf:Agent`, being it either an `Organization` or a `Person`, with an `obo-bfo:Role`.
- `roh:Justification` through relationship `vivo:relates` binds justifications with a `vivo:Project`.
- `foaf:Person`, where an person may play different `obo-bfo:Roles`, e.g. `vivo:PrincipalInvestigatorRole` or `vivo:ResearcherRole`.
- `vivo:ProjectContract` subtype of `vivo:Contract`, a project may be associated to a contract through relationship `roh:hasContract`.
- `roh:ProjectExpense` is `roh:spentBy` a project, details allows to associate a project with its expenses.
- `roh:ResearchObject`, where a project `roh:produces` several `roh:ResearchObject`, where some results of a project might be for example of types `bibo:Journal`, `obo-iao:JournalArticle`, or `roh:PhDThesis`.

Notice that a `vivo:Project` may also be part (`obo-ro:BFO_0000051`) of another project, e.g. child of a parent project. Besides, every instance of a `vivo:Project` is time bound by being associated with an instance of `vivo:DateTimeInterval` and geographically bound to an instance of `gn:Feature` (through relationship (`gn:locatedIn`).

The following table shows the object and data properties associated to `vivo:Project`:

Prefix	Class	Prefix	**Object property** (bold indicates explicit Domain, otherwise a Restriction)	Range Class	Prefix	**Datatype Property** (bold indicates explicit domain; otherwise a restriction)	**Range Datatype** (if typed)	Range values
vivo	**Project**	roh	hasKnowledgeArea	skos:Concept and (skos:inScheme some roh:Knowledge Area)	roh	identifier	xsd:string	
		vivo	relates	obo-bfo:BFO_0000023 (Role)	vivo	abbreviation	rdfs:Literal	
		roh	hasContract	vivo:ProjectContract	vivo	description	rdfs:Literal	
		obo-ro	BFO_0000051 (hasPart)	vivo:Project	roh	title	xsd:string	
		vivo	participates	roh:Activity	vivo	freeTextKeyword	xsd:string	
		roh	spends	roh:ProjectExpense	roh	**modality**	xsd:string	
		roh	produces	roh:ResearchObject	roh	**needsEthicalValidation**	xsd:boolean	
		vivo	relatedBy	roh:Dossier or roh:Justification or obo-bfo:BFO_0000023 (Role)	roh	**isCompetitive**	xsd:boolean	
		roh	**isSupportedBy**	roh:Funding	roh:	**projectObjective**	xsd:string	
		gn	locatedIn	gn:Feature				
		vivo	dateTimeInterval	vivo:DateTimeInterval				
		roh	**hasProjectCategorization**	(skos:Concept and (skos:inScheme some roh:ProjectClassification)				
		roh	**hasHRClassification**	(skos:Concept and (skos:inScheme some roh:HRClassification))				
		roh	**projectStatus**	roh:Status (roh:Closed or roh:Open or roh:ProposalSubmitted or roh:Rejected)				
		roh	**coordinatedBy**	foaf:Agent				
		roh	**foreseenJustificationDate**	vivo:DateTimeValue				

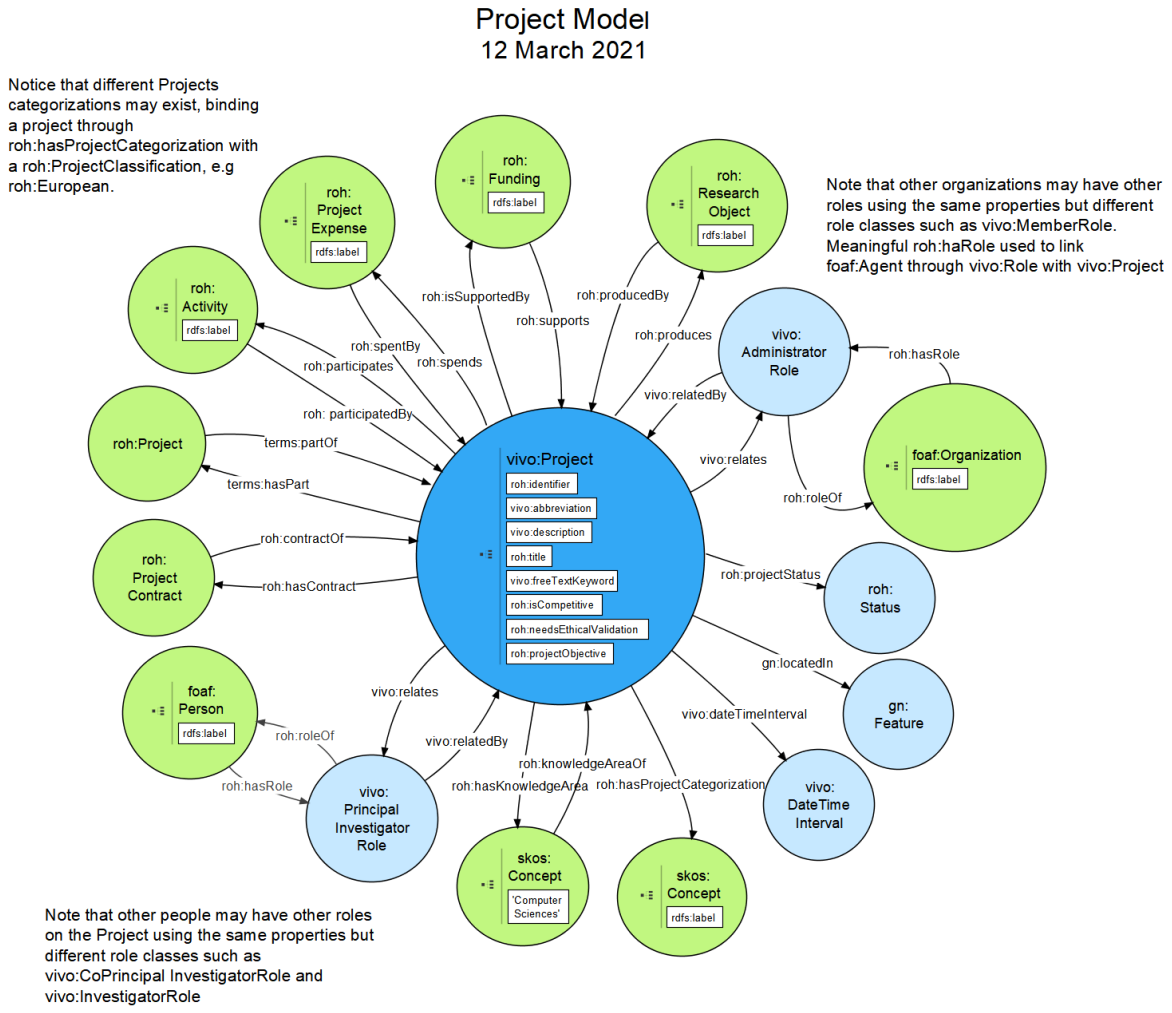

Figura 3. Ontological diagram for entity `Project`.

1.4. Entity Person

In ROH, there is a `foaf:Person` entity (see Figura 4) that inherits from `foaf:Agent`. The specialization of this entity imported from the VIVO ontology already adds some DataType properties of the research domain, but in ROH we also incorporate `roh:taxID`, `roh:ORCID`, `vivo:researcherId` or `vivo:scopusId` (all of them are subtypes of `vivo:identifier`, a given person may use or several alternatives of those identifiers) and also several object specific properties of the research domain as "has a Role" (`roh:hasRole`) in an Organization, "has a CurriculumVitae" (`roh:hasCV`), "has some Accreditations" (`roh:hasAccreditation`), "has an Employment Contract" (`roh:hasContract`), "has some Knowledge Areas" (`roh:hasKnowledgeArea`) or "has

some Roles" (roh:hasRole) in Projects or participates through "bibo:authorList" with Research Objects of subclass bibo:Document. A person can "have different roles" in the Project over time. As a subclass of foaf:Agent inherits some additional object properties such as roh:hasAccreditation or roh:hasContactInfo.

As mentioned above, foaf:Person in ROH is based on FOAF (Friend of a Friend [2], following patterns used in VIVO. That explains why it includes some of the basic FOAF properties such as foaf:name, foaf:nickname, foaf:title, foaf:mbox (note that this in fact an object property), foaf:img (note that this in fact an object property), vivo:description, foaf:firstName and foaf:surname. However, it considers all attributes and links defined in CERIF through the cfPers entity. foaf:Person incorporates the following data properties declared as attributes in cfPers, especially: identifier (vivo:identifier but preferably roh:ORCID), roh:birthdate, foaf:gender, foaf:homepage (note that this in fact an object property), roh:researchLine, vivo:freeTextKeyword. Some important CERIF relationships that have also been adopted: Curriculum Vitae (roh:hasCV) which links foaf:Person with roh:CurriculumVitae, Event (roh:Activity) and Indicator (roh:Accreditation).

Besides, an instance of a foaf:Person is associated to the following entities through object properties:

- roh:AuthorMetric, where a researcher may have associated metric values such as h-index or i10 index.
- roh:AcademicSubject, where a researcher teaches different subjects.
- vivo:AwardedDegree, where a researcher vivo:relates with an roh:AcademicDegree
- roh:Accreditation, where a researcher roh:hasAccreditation of different types, e.g. roh:ResearchAccreditation or roh:AcademicAccreditation.
- roh:Activity, where a researcher roh:participates in diverse activities, e.g. vivo:InvitedTalk or bibo:Conference.
- skos:Concept is linked through roh:knowledgeAreaOf to a person, indicating the different knowledge areas (roh:KnowledgeArea) a researcher is specialized on.
- roh:CurriculumVitae, where a researcher roh:hasCV which includes a data type property like roh:summary. A researcher is also bound to author metrics roh:AuthorMetric through property roh:hasMetric.

- `bibo:Document`, `roh:ExperimentalProtocol`, and `obo-ero:ERO_0000071(Software)`, where a researcher through `roh:seqOfAuthors` is participating in a `bibo:Document`, `roh:ExperimentalProtocol` or `obo-ero:ERO_0000071(Software)` as one of its authors. In the case of `bibo:Document` the object property `bibo:AuthorList` also can be used.
- `vcard:Individual`, where a researcher `roh:hasContactInfo` described through ontology vcard.
- `vivo:Position`, where a researcher `roh:hasPosition` usually in an organization linking it to any of the `vivo:Position` subclasess like `vivo:FacultyAdministrativePosition` or `vivo:FacultyPosition`.
- `vivo:PersonExpense`, where a researcher may contribute with several expenses for its research activities.
- `roh:ResearchObject`, where a researcher is the `roh:correspondingAuthor` of different subtypes of `roh:ResearchObject`, e.g. `obo-iao:JournalArticle`, `vivo:ConferencePaper` or `bibo:Proceedings`.
- `obo-bfo:BFO_0000023` (Role), where a `foaf:Agent` may `roh:hasRole` like `vivo:ResearcherRole` or `vivo:TeacherRole` either in a `vivo:Project` or a `foaf:Organization`.
- `roh:PersonContract`, where a researcher `roh:hasContract` described according to the attributes corresponding to parent class `vivo:Contract`.
- `bibo:Thesis`, where a researcher is `roh:supervisorOf` of a `bibo:Thesis`, concretely, any of its subtypes subclasess like `roh:MasterThesis` or `roh:PhDThesis`.

The following table fully describes the object and data properties defined within the `foaf:Person` entity in ROH.

Prefix	Class		Prefix	Object property (bold indicates explicit Domain, otherwise a Restriction)	Range Class	Prefix	Datatype Property (bold indicates explicit domain; otherwise a restriction)	Range Datatype (if typed)	Range values
foaf	**Agent**		roh	**hasContactInfo**	vcard:Kind	vivo	freeTextKeyword	xsd:string	
			roh	**hasAccreditation**	roh:Accreditation				
			roh	**hasRole**	obo-bfo:BFO_0000023 (Role)				
			foaf	**mBox**	owl:Thing				
			vivo	relatedBy	vivo:Relationship				
			roh	**hasReservable**	roh:Reservable				
	foaf	**Person**	roh	hasKnowledgeArea	(skos:Concept and (skos:inScheme some roh:KnowledgeArea))	vivo	identifier	xsd:string	
			vivo	relates	vivo:AwardedDegree	vivo	**researcherId**		
			roh	spends	roh:PersonExpense	roh	birthdate	xsd:string	
			roh	hasContract	roh:PersonContract	vivo	**eRACommonsId**		
			roh	**hasCV**	roh:CurriculumVitae	roh	description	xsd:string	
			roh	**hasPosition**	vivo:Position	roh	**firstName**	xsd:string	
			roh	participates	roh:Activity	roh	**gender**	xsd:string	
			roh	**hasMetric**	roh:AuthorMetric	roh	researchLine	xsd:string	
			foaf	homePage	foaf:Document	foaf	**surname**	xsd:string	
			foaf	**image**	foaf:Image	foaf	name	xsd:string	
			roh	**correspondingAuthor**		foaf	nickname	xsd:string	
			roh	**supervisorOf**	bibo:Thesis	roh	**taxID**	xsd:string	
			roh	**teaches**	roh:AcademicSubject	roh	title	xsd:string	
			roh	**reviews**	bibo:Document	roh	**ORCID**	xsd:string	
						vivo	**scopusId**		
						roh	dedication	xsd:string	{"PARTIAL", "TOTAL"}

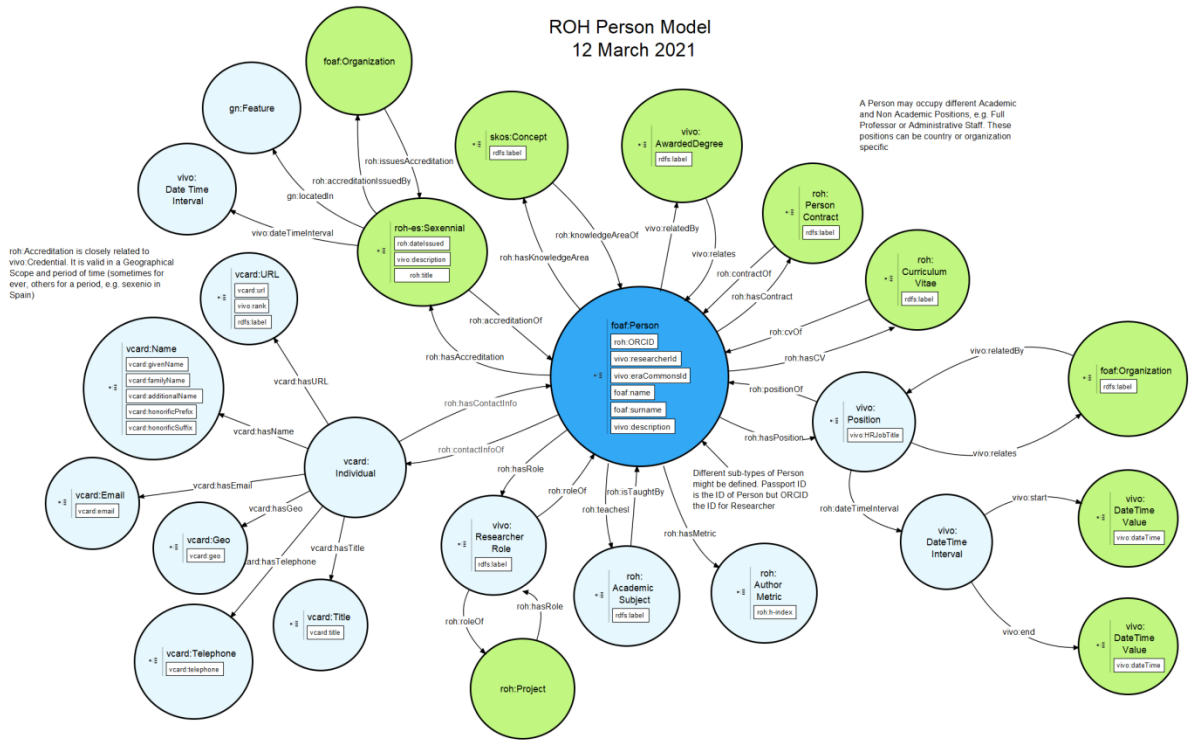

Figura 4. Ontological Diagram for entity `Person`.

1.5. Organization entity

An Organization in ROH (see Figura 5) is a `foaf:Organization` which carries out several `vivo:Project`. It is a child of `foaf:Agent`. Some organization can emit `roh:Acreditation` (e.g. ANECA or CENAI in Spain), those belonging to subclass `roh:AccreditationIssuer`, or award degrees (`vivo:AwardedDegree`), those of subclass `vivo:University`. An Organization may receive several `roh:FundingAmount`, corresponding to a `roh:Funding`, obtained through a `roh:FundingProgram` provided by a `vivo:FundingOrganization` through a `roh:FundingSource`. As a `foaf:Agent` an Organization may be involved in several `roh:Actitity`, has several instances of attribute `vivo:freetextKeyword`, is associated through `roh:hasKnowledgeArea` with `roh:KnowledgeArea` and bound to a geographical scope through `gn:locatedIn` with `gn:Feature`, it may also have a time span through `vivo:dateTimeInterval` linking it with an instance of `vivo:DateTimeInterval`.

Based on FOAF [10], the `foaf:Organization` entity takes into account the data properties (attributes: `vivo:abbreviation`, `foaf:homepage`) and data properties (links) defined by the `Organization Unit` in CERIF. It also takes into account and supports the relationships of CERIF Equipment (via entity `vivo:Equipment` and object property `roh:hasReservable`), Event (`roh:Activity`), Expertise and Skill (via `vivo:freeTextKeyword` and `roh:hasKnowledgeArea`), Facility (`roh:Facility` and `roh:hasReservable`), Funding (`roh:Funding`), Organization Unit (kinship relationships between organizations can be established with `obo-ro:BFO_0000051 (has part)` and `obo-ro:BFO_0000051 (part of)`, Prize Award (through `roh:Accreditation`), Result Patent, Result Product, Result Publication and Service - all of them through `roh:ResearchObject` which can be obtained through the `roh:produces` relationship from the Projects in which an organization participates by playing a declared role through `roh:hasRole`, Person (through `roh:hasPosition`). Therefore, the CERIF data model for Organization is covered.

An exhaustive hierarchy of organizations is included, e.g. `roh:AccreditationIssuer`, `vivo:Company` or `vivo:University`, among many others.

Besides, an instance of a `foaf:Organization` is associated to the following entities through object properties:

- `roh:Accreditation`, where an organization of type `roh:AccrediationIssuer` issues (`roh:issues`) accreditations, e.g. `roh:ResearchAccreditation` or `roh:AcademicAccreditation`.
- `roh:Activity`, where an organization may play `vivo:OrganizerRole` through `roh:hasRole` in an activity or may through its participation role in a project participate (`roh:participates`) in an activity.
- `vivo:AwardedDegree`, where a `vivo:University` may `roh:awards` degrees which are related to both a concrete `vivo:AcademicDegree` and an instance of `foaf:Person`.
- `skos:Concept`, where an organization through `roh:hasKnowledgeArea` may be associated to several knowledge areas, defined as instance data of thesaurus created with SKOS ontology. A concept linked to an organization must necessary belong to `roh:KnowledgeArea` concept scheme.
- `vivo:Company`, where an organization might be linked to several spinoffs through object property `roh:hasSpinOff`.

- `vivo:DateTimeInterval`, where an organization may exist during a given time interval
- `foaf:Document`, where an organization may be associated to several homepages `foaf:homePage`
- `gn:Feature` through relationship `gn:locatedIn`, where an organization may be associated a geographical scope.
- `roh:FundingAmount` where an organization may receive several funding amounts part of a `roh:Funding` through `roh:grants` object property.
- `vcard:Organization`, where an organization `roh:hasContactInfo` described through ontology vcard.
- `roh:PatentApplication` or `bibo:Patent` where an organization is the owner (`roh:ownerOrganizationOf`) of different patent applications or granted patents. Notice that a `roh:PatentApplication` goes through different status (`roh:patentStatus`) and is associated with a granted patent (`bibo:Patent`), once its status passes to be `roh:Accepted`, through object property (`roh:hasPatent`).
- `roh:Reservable`, where an organization may `roh:hasReservable`, belonging to any of its subclasses, e.g. `roh:Equipment`, `roh:Facility` or `obo-ero:ERO_0000071` (Software).
- `foaf:Organization`, where a `foaf:Organization` may be linked through `vivo:hasSucessorOrganization` or `vivo:hasPredecessorOrganization` with another `foaf:Organization` or may be part of (`obo-ro:BFO_0000050 (part of)`) or include (`obo-ro:BFO_0000051 (has part)`) other several `foaf:Organization`.
- `obo-ero:ERO_0000005 (Service)`, where an organization `roh:provides` several services, e.g. `obo-ero:ERO_0000392` (Storage Service)
- `roh:ResearchObject`, where a `foaf:Organization` may be linked through `roh:correspondingOrganization` with some `roh:ResearchObject`.

Check the following table for more details on object and data properties for `foaf:Organization`.

Prefix	Class		Prefix	Object property (bold indicates explicit Domain, otherwise a Restriction)	Range Class	Prefix	Datatype Property (bold indicates explicit domain; otherwise a restriction)	Range Datatype (if typed)	Range values
foaf	**Agent**		roh	hasContactInfo	vcard:Kind	vivo	freeTextKeyword	xsd:string	
			roh	**hasAccreditation**	roh:Accreditation				
			roh	**hasRole**	obo-bfo:BFO_0000023 (Role)				
			foaf	**mBox**	owl:Thing				
			vivo	relatedBy	vivo:Relationship				
			roh	**hasReservable**	roh:Reservable				
	foaf	**Group**							
	foaf	**Organization**	roh	hasKnowledgeArea	(skos:Concept and (skos:inScheme some roh:KnowledgeArea))	vivo	identifier	xsd:string	
			vivo	**affiliatedOrganization**	foaf:Organization	vivo	abbreviation	rdfs:Literal	
			roh	correspondingOrganizationOf	roh:ResearchObject				
			roh	**foundationDate**	vivo:DateTimeValue	vivo	description	xsd:string	
			vivo	**hasSuccessorOrganization**	foaf:Organization	roh	title	xsd:string	
			vivo	**hasPredecessorOrganization**	foaf:Organization				
			obo-ro	BFO_0000051 (hasPart)	foaf:Organization				
			roh	hasReservable	roh:Reservable				
			roh	hasSpinOff	vivo:Company				
			foaf	homePage	bibo:Document				
			roh	**ownerOrganizationOf**	roh:PatentApplication or bibo:Patent				
			roh	participates	roh:Activity				
			roh	produces	roh:ResearchObject				
			roh	**provides**	obo-ero:ERO_0000005 (Service)				
			roh	grantedBy	roh:FundingAmount				
			vivo	dateTimeInterval	vivo:DateTimeInterval				
			gn	locatedIn	gn:Feature				
		roh AccreditationIssuer[1]	roh	**issues**	roh:Accreditation				

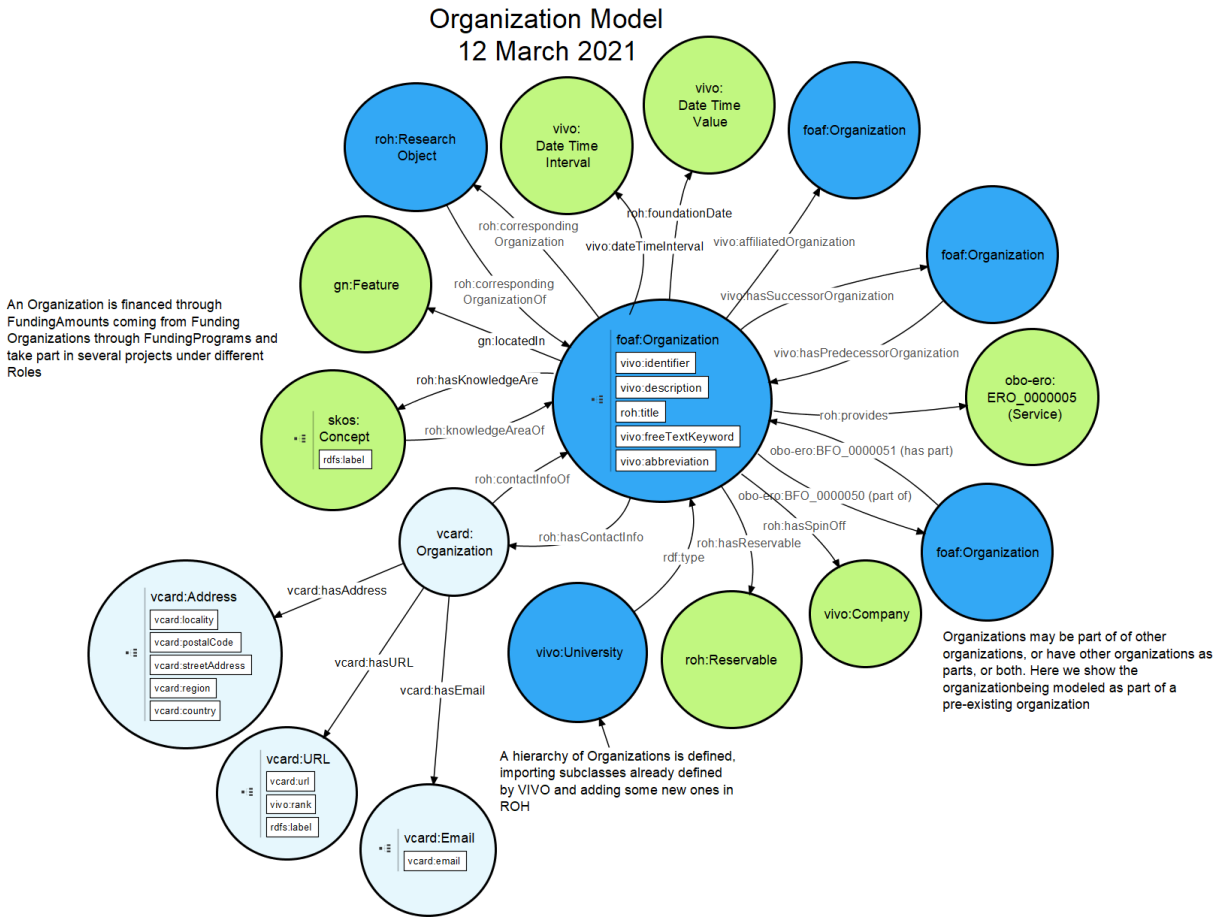

Figura 5. Ontological diagram for entity `Organization`.

1.6. Funding entity

The `roh:Funding` entity (see Figure 6), new in ROH, represents the funding associated with a project (`vivo:Project`) whose funding is associated with a funding program (`roh:FundingProgram`) and comes from a (`roh:FundingSource`), which in turn is associated with a funding organization (`vivo:FundingOrganization`). A funding is divided into several amounts (`roh:FundingAmount`), associated with the different entities that participate in a project and the annuities in which they do so. Funding amounts for an organization in a projects are expressed through data properties `roh:monetaryAmount` and `roh:currency`.

A funding can be marked as public through property `roh:publicFunding`, qualified by properties `vivo:identifier`, `vivo:description` and `vivo:freeTextKeyword` and classified into `roh:Grant`, `roh:Loan`, `roh:Outsourcing` or `roh:RefundableAdvance`.

The funding organization (`vivo:FundingOrganization`) (see Figure 6), imported from VIVO [1], inherits from `foaf:Organization`, promotes (`roh:promotes`) research through different funding programs (`roh:FundingProgram`) and through different funding sources (`roh:FundingSource`). A `roh:Funding` is associated with `roh:FundingAmount`s through object property `obo-ro:BFO_0000051 (has part)`. A `roh:FundingProgram` funds (`roh:funds`) a `roh:Funding`, funding programs are promoted by `roh:FundingOrganization`s. Notice that a `roh:Funding` is divided into several `roh:FundingAmount`s associated with different `foaf:Organization`s through the `roh:grants` relationship.

The Funding Program entity (`roh:FundingProgram`) (see Figure 6), new in ROH, defines the funding initiatives promoted (`roh:promotedBy`) by a Funding Organization (`roh:FundingOrganization`) which is, likewise, promoted by a `roh:FundingSource`. A funding is in operation during a time interval (`vivo:dateTimeInterval`) and is usually linked to a geographical scope (`geonames:Feature`) associated to the `roh:FundingProgram`.

The following table illustrates the object and data properties associated to entities dealing with the funding concept in ROH.

Prefix	Class		Prefix	Object property (bold indicates explicit Domain, otherwise a Restriction)	Range Class	Prefix	Datatype Property (bold indicates explicit domain; otherwise a restriction)	Range Datatype (if typed)	Range values
roh	**Funding**		obo-ro	BFO_0000051 (has part)	roh:FundingAmount	vivo	identifier	xsd:string	
			vivo	dateTimeInterval	vivo:DateTimeInterval	vivo	description		
			roh	**fundedBy**	roh:FundingProgram	vivo	freeTextKeyword		
			roh	hasContract	vivo:Contract	roh	**publicFunding**	xsd:boolean	
			roh	hasKnowledgeArea	(skos:Concept and (skos:inScheme some roh:KnowledgeArea))				
			roh	**supports**	roh:PersonContract or roh:Project				
	roh	Grant							
	roh	Loan							
	roh	Outsourcing							
	roh	RefundableAdvance							
roh	**FundingAmount**		obo-ro	BFO_0000050 (part of)	roh:Funding	roh	currency	xsd:string	
			vivo	dateTimeInterval	vivo:DateTimeInterval	roh	monetaryAmoung	xsd:float	
			roh	**grants**	foaf:Organization				
roh	**FundingProgram**		obo-ro	BFO_0000051 (has part)	roh:FundingProgram	vivo	description	xsd:string	
			vivo	dateTimeInterval	vivo:DateTimeInterval	vivo	identifier	xsd:string	
			roh	hasFundingProgramClassification	(skos:Concept and (skos:inScheme some roh:FundingProgramClassification))	roh	title	xsd:string	
			gn	locatedIn	gn:Feature				
			roh	**promotedBy**	vivo:FundingOrganization				
			roh	**funds**	roh:Funding				
			vivo	relatedBy	roh:Dossier				
roh	**FundingSource**		roh	funds	roh:FundingProgram				
			roh	**promotedBy**	vivo:FundingOrganization				

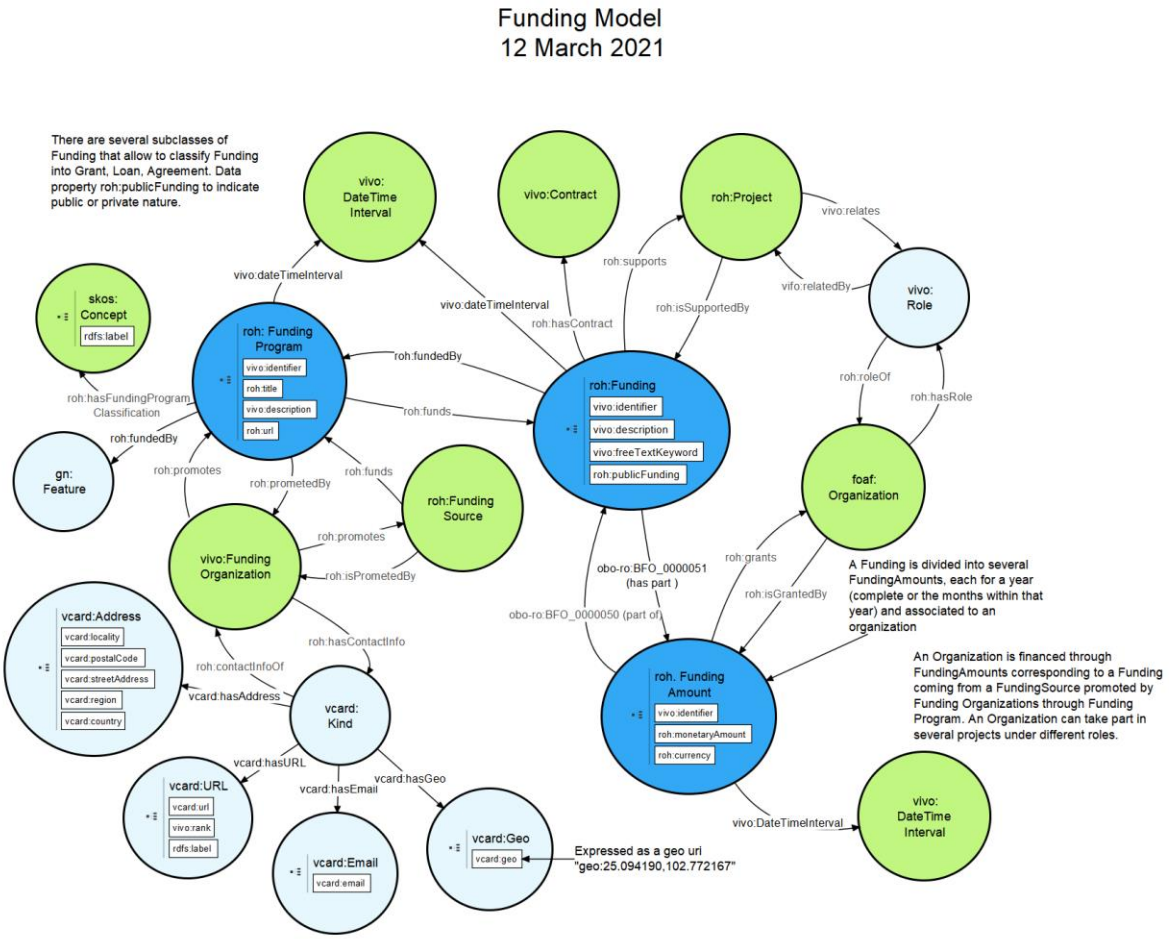

Figure 6. Ontological diagram for `Funding`.

1.7. Research Result and Research Object Entities

The research object entity (`roh:ResearchObject`) is a new entity defined in ROH that corresponds to a research result (`roh:ResearchResult`) generated by a person (researcher), usually through work on a project. Notice that `roh:ResearchObject` is a subclass of `roh:ResearchResult` and a defined class, which follows these restrictions: `('part of research result' some 'Research Result') or ('produced by' only vivo:Project)`. This is, an instance in ROH belongs to class `roh:ResearchObject` if it meets these restrictions. Usually a `roh:ResearchObject` results from working on a `vivo:Project` (`roh:produces`), which is modelled with the second constraint `('produced by' only vivo:Project)`. Regarding the first restriction, an instance of `ero:software`, `bibo:Document` and

roh:ExperimentalProtocol is a research object only if this instance is part of (roh:partOfResearchResult) some roh:ResearchResult declared by some researcher. Thus, each roh:ResearchResult and the roh:ResearchObjects that compose it are specific to the author who creates the research result and declares its elements. So, if an article is created by two researchers, one of them can declare it as a research object making this article part of his research result, while the other researcher can not declare it if he does not want to.

A research object has been modelled, around entities obo-iao: IAO_0000030 (Information Content Entity), roh:ExperimentalProtocol, and obo-ero:ERO_0000071. Such entities are linked to at least one foaf:Person through object property roh:correspondingAuthor. The contributors of a research object are accessible through object property roh:seqOfAuthors, or in the case of bibo:Document (subclass of obo-iao: IAO_0000030 (Information Content Entity)) the contributors are also accessible through object property bibo:authorList. The primary author of a research object is accessible through the roh:correspondingAuthor property and the responsible organization of a research object is accessible through roh:correspondingOrganization. A roh:ResearchObject may have several knowledge areas bound to it through roh:hasKnowledgeArea, where the linked concepts should be associated to concept scheme roh:KnowledgeArea or one of its subclasses. The vertical module knowledge-area contains relevant instance data scientific domains, research subjects and UNESCO codes.

Prefix	Class		Prefix	**Object property** (bold indicates explicit Domain, otherwise a Restriction)	Range Class	Prefix	**Datatype Property** (bold indicates explicit domain; otherwise a restriction)	**Range Datatype** (if typed)	Rang value
roh	**ResearchResult**		roh	hasKnowledgeArea	skos:Concept and (skos:inScheme some roh:Knowledge Area)	roh	identifier	xsd:string	
			roh	researchResultHasPart	roh:ExperimentalProtocol or roh:Repository or bibo:Document or ero:ERO_0000071 or vivo:Project	roh	title	xsd:string	
			roh	seqOfAuthors	rdf:Seq	vivo	abbreviation	rdfs:Literal	
			roh	hasSucessor	roh:ResearchResult	vivo	description	rdfs:Literal	
			roh	correspondingAuthor	foaf:Person	vivo	freeTextKeyword	xsd:string	
			vivo	dateTimeInterval	vivo:DateTimeInterval	roh	**needsEthicalValidation**	xsd:boolean	
	roh	**ResearchObject**[1]	roh	correspondingOrganization	foaf:Organization	roh	language	xsd:string	
			roh	hasPartOfResearchResult	roh:ResearchResult				
			roh	**producedBy**	roh:Project				

1.7.1. obo-iao: IAO_0000030 (Information Content Entity) Entity

Under `obo-iao: IAO_0000030 (Information Content Entity)` entity a complete taxonomy of entities mostly imported from BIBO [4], covering all kinds of publications, patents, and web pages, is defined. Some examples are: `bibo:Collection`, `bibo:Journal`, `bibo:Article`, `bibo:Book`, `bibo:Chapter`, `vivo:DataSet`, `bibo:Patent`, `bibo:Thesis` and `bibo:Webpage`.

The concept publication it's the most important and is defined mainly through the imported entity `bibo:Document`. Currently, the following sets of entities related to the publication concept are supported: `bibo:Collection` (Newspaper, Magazine) and `bibo:Document` (Article, ConferencePaper, EditorialArticle, Book, Proceedings, ConferencePaper, Chapter, Thesis). `bibo:Thesis` has been refined into `roh:BachelorsThesis`, `roh:MastersThesis` and `roh:PhDThesis`.

Two entities worth mentioning that belong to the hierarchy of classes associated to the `vivo:Project` are: `bibo:Report` and `roh:Dossier`. A `bibo:Report` has been refined to include subclasses `roh:EthicalReport` (which includes `roh:EthicalAudit` and `roh:EthicalValidation`), `roh:EvaluationSummary`, `roh:Justification` and `roh:ResearchProposal`. This implies that a report may correspond to ethical validation and auditing needs of a project, correspond to the evaluation of the project, its proposal or the set of documents corresponding to its justification. On the other that represents a collection of reports related to a `vivo:Project`, which may include all the types of reports above mentioned.

Prefix	**Class**				**Prefix**	**Object property** (bold indicates explicit Domain, otherwise a Restriction)	**Range Class**	**Prefix**	**Datatype Property** (bold indicates explicit domain; otherwise a restriction)	**Range Datatype** (if typed)	**Range values**
obo-iao	**IAO_0000030 (Information Content Entity)**				roh	correspondingOrganization	foaf:Organization	roh	language	xsd:string	
	bibo	**Collection**						bibo	oclcnum	rdfs:Literal	
		roh	Dossier		vivo	dateTimeInterval	vivo:DateTimeInterval	vivo	description	rdfs:Literal	
					vivo	relates	roh:FundingProgram or roh:ProjectContract or bibo:Report or vivo:Project	vivo	identifier	xsd:string	
								roh	title	xsd:string	
		bibo	Periodical		vivo	publisher	foaf:Organization	bibo	eissn	rdfs:Literal	
								bibo	issn	rdfs:Literal	
			bibo	Journal				vivo	abbreviation	rdfs:Literal	
			bibo	Magazine							

Prefix	Class			Prefix	Object property (bold indicates explicit Domain, otherwise a Restriction)	Range Class	Prefix	Datatype Property (bold indicates explicit domain; otherwise a restriction)	Range Datatype (if typed)	Range values
obo-iao	**IAO_0000030 (Information Content Entity)**			roh	correspondingOrganization	foaf:Organization	roh	language	xsd:string	
	bibo	**Document**		bibo	**authorList**	rdf:Seq	bibo	abstract	xsd:string	
				roh	correspondingAuthor	foaf:Person	bibo	doi	xsd:string	
				roh	correspondingOrganization	foaf:Organization				
				roh	partOfRepository	roh:Repository	roh	title	xsd:string	
				roh	partOfResearchResult	roh:ResearchResult				
				vivo	dateTimeValue	vivo:DateTimeValue	vivo	freeTextKeyword	xsd:string	
				bibo	**editorList**	rdf:Seq	bibo	**pageStart**	rdfs:Literal	
				vivo	hasPublicationVenue	bibo:Collection or bibo:Book	bibo	**pageEnd**	rdfs:Literal	
				vivo	**publisher**	foaf:Agent				
				cito	**cites**	roh:ExperimentalProtocol or ero:ERO_0000071 or roh:Repository or bibo:Document				
				roh	documentStatus	roh:Accepted or roh:Rejected				
		roh	README	roh	readmeOf	roh:Repository or ero:ERO_0000071				
		roh	ExperimentalProtocolResult							
		vivo	Abstract							
		bibo	Article				bibo	**issue**		
			bibo Academic Article	**vivo**	**hasPublicationVenue**	**bibo:Journal**	bibo	eanucc13	rdfs:Literal	
			obo-iao: IAO_0000013 (JournalArticle)	vivo	dateTimeValue	vivo:DateTimeValue				
				roh	**hasMetric**	roh:PublicationMetric				
			roh:PeerReviewedArticle							
			roh BlogPost							
			vivo ConferencePaper	bibo	presentedAt	bibo:Conference				
			roh: WorkshopPaper							
			vivo EditorialArticle							
			roh PeerReviewedArticle							
			roh PressArticle							
		bibo	AudioVisualDocument							
			roh RadioProgram							
			roh TvProgram							
		bibo	Book	vivo	publisher	foaf:Organization	bibo	edition	rdfs:Literal	
							bibo	isbn	rdfs:Literal	
							bibo	iccn	rdfs:Literal	
							vivo	placeOfPublication	rdfs:Literal	
			bibo Proceedings							
		roh	CaseStudy							
		roh	Catalog							

		bibo	CollectedDocument							
			roh: Database							
			bibo: EditedBook							
			bibo: Issue	obo-ro	BFO_0000051 (hasPart)	bibo:Article	bibo	issue	rdfs:Literal	
		vivo	ConferencePoster							
		roh	CurriculumVitae	roh	**CVOf**	foaf:Person	roh	summary	xsd:string	
		vivo	Dataset	cito	isCitedAsDataSourceBy	bibo:Document				
		bibo	DocumentPart	vivo	publisher	foaf:Organization	vivo	placeOfPublication	rdfs:Literal	
			bibo: BookSection				bibo	edition	rdfs:Literal	
			bibo: Chapter							
		roh	EditedPublication							
		foaf	Image							
		roh	Invoice							
			roh: ProformaInvoice							
		bibo	Manual							
		bibo	Patent	**vivo**	**assignee**	**foaf:Organization**	**vivo**	**identifier**	xsd:string	
				vivo	dateIssued	vivo:DateTimeValue	roh	modality	xsd:string	
				roh	expirationDate	vivo:DateTimeValue				
				roh	hasKnowledgeArea	(skos:Concept and (skos:inScheme some roh:KnowledgeArea))				
				gn	locatedIn	gn:Feature				
				roh	ownerOrganization	foaf:Organization				
				roh	**patentCountry**	(skos:Concept and (skos:inScheme some roh:Country))				
				roh	**patentInventor**	foaf:Person				
		bibo	Report	bibo	distributor	foaf:Organization				
				vivo	publisher	foaf:Organization				
			roh: EthicalReport							
			roh: EthicalAudit							
			roh: EthicalValidation							
			roh: EvaluationSummary	roh	evaluationStatus	roh:Final or roh:Provisional				
			roh: Justification	vivo	relates	roh:Project				
			vivo: ResearchProposal	vivo	relates	roh:Justification or roh:ProjectContract or roh:Project or vivo:ResearchProposal				
			roh: TechnicalReport							
		bibo	Thesis	**roh**	**supervisedBy**	foaf:Person	vivo	abbreviation	rdfs:Literal	
							vivo	placeOfPublication	rdfs:Literal	
			roh: BachelorsThesis							
			roh: MastersThesis							
			roh: PhDThesis							
		bibo	Webpage							

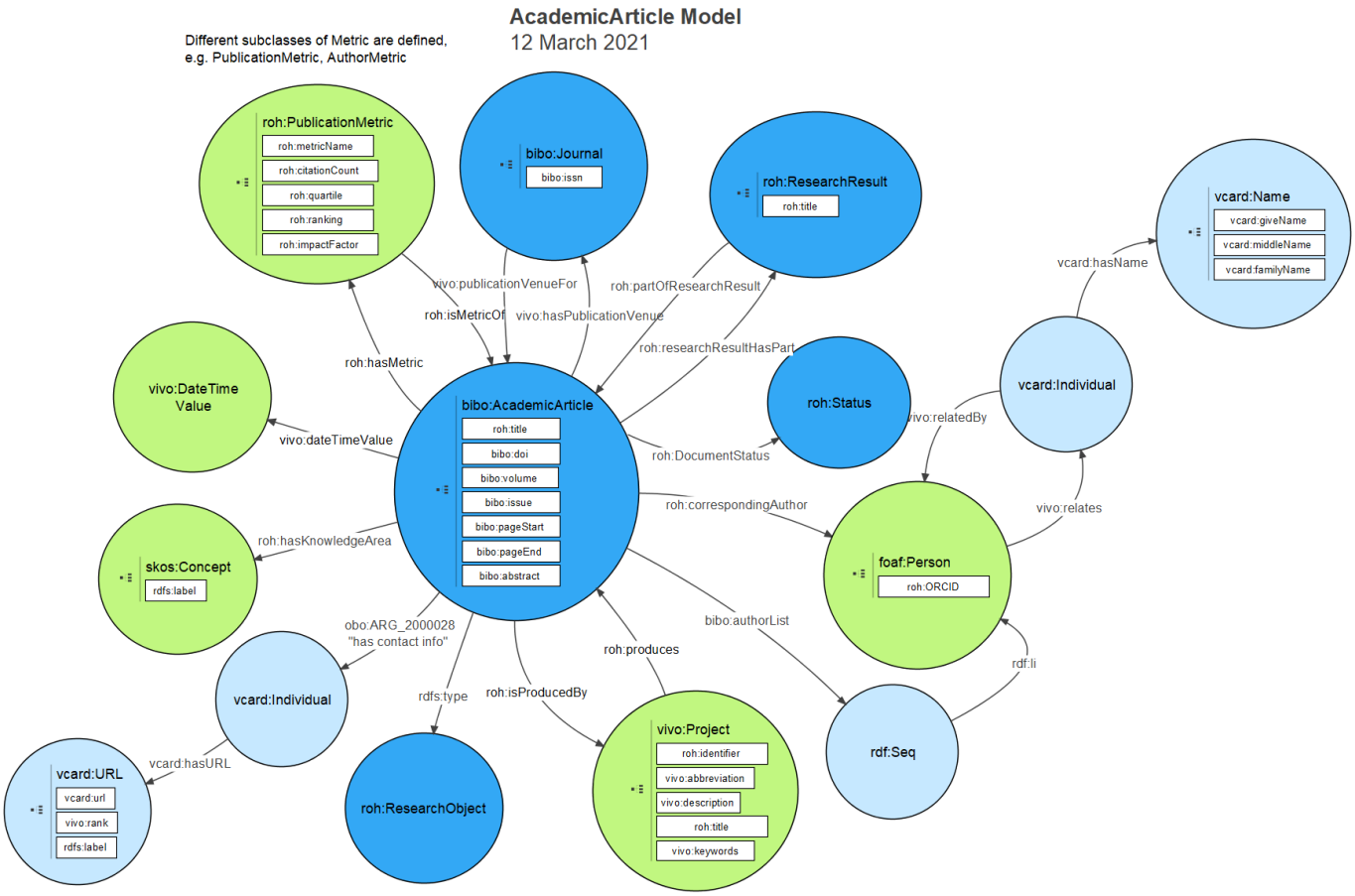

Figure 7. Ontological diagram for `AcademicArticle`.

Another important sub-entity of `obo-iao: IAO_0000030 (Information Content Entity)` is `roh:Repository` (see Figure 8). Documents, pieces of software, experimental protocols or data can be linked to repository (`roh:Repository`) that contains them through the object property `roh:partOfRepository`. `roh:Repository` is associated through `roh:hasSucessor` with another `roh:Repository` when it is a predecessor or fork of the first one, and through `roh:hasReadme` with the document describing the structure of the repository `roh:README`. This entity can be linked with the contributors through `roh:seqOfAuthors`, to the primary author (`foaf:Person`) through `roh:correspondingAuthor`, to corresponding organization (`foaf:Organization`) through `roh:correspondingOrganization`.

The following table illustrates the object and data properties associated to entity `roh:Repository`, which is a subclass of `obo-iao: IAO_0000030 (Information Content Entity.`

Prefix	Class			Prefix	**Object property** (bold indicates explicit Domain, otherwise a Restriction)	Range Class	Prefix	**Datatype Property** (bold indicates explicit domain; otherwise a restriction)	Range Datatype (if typed)	Range values
obo-iao	**IAO_0000030 (Information Content Entity)**			roh	correspondingOrganization	foaf:Organization	roh	language	xsd:string	
	roh	**Repository**		roh	correspondingAuthor	foaf:Person	roh	title	xsd:string	
				roh	hasKnowledgeArea	(skos:Concept and (skos:inScheme some roh:KnowledgeArea))	vivo	description	xsd:string	
				roh	hasReadme	roh:README	bibo	abstract	xsd:string	
				cito	cites	roh:ExperimentalProtocol or ero: ERO_0000071 or roh:Repository or bibo:Document	vivo	freeTextKeyword	xsd:string	
				roh	repositoryHasPart	ExperimentalProtocol or bibo:Document or ero: ERO_0000071				
				roh	hasPredecessor	roh:Repository				
				roh	seqOfAuthors	rdf:Seq				
				roh	hasLicense	vivo:License				
				roh	repositoryStatus	roh:Closed or roh:Open				
				vivo	dateTimeValue	vivo:DateTimeValue				
				foaf	homePage	bibo:Webpage				
		roh	BitBucketRepository	roh	hasPredecessor	roh: BitBucketRepository				
		roh	GitHubRepository	roh	hasPredecessor	roh:GitHubRepository				
		roh	ZenodoRepository	roh	hasPredecessor	roh: ZenodoRepository	bibo	doi	xsd:integer	
							vivo	identifier	xsd:integer	

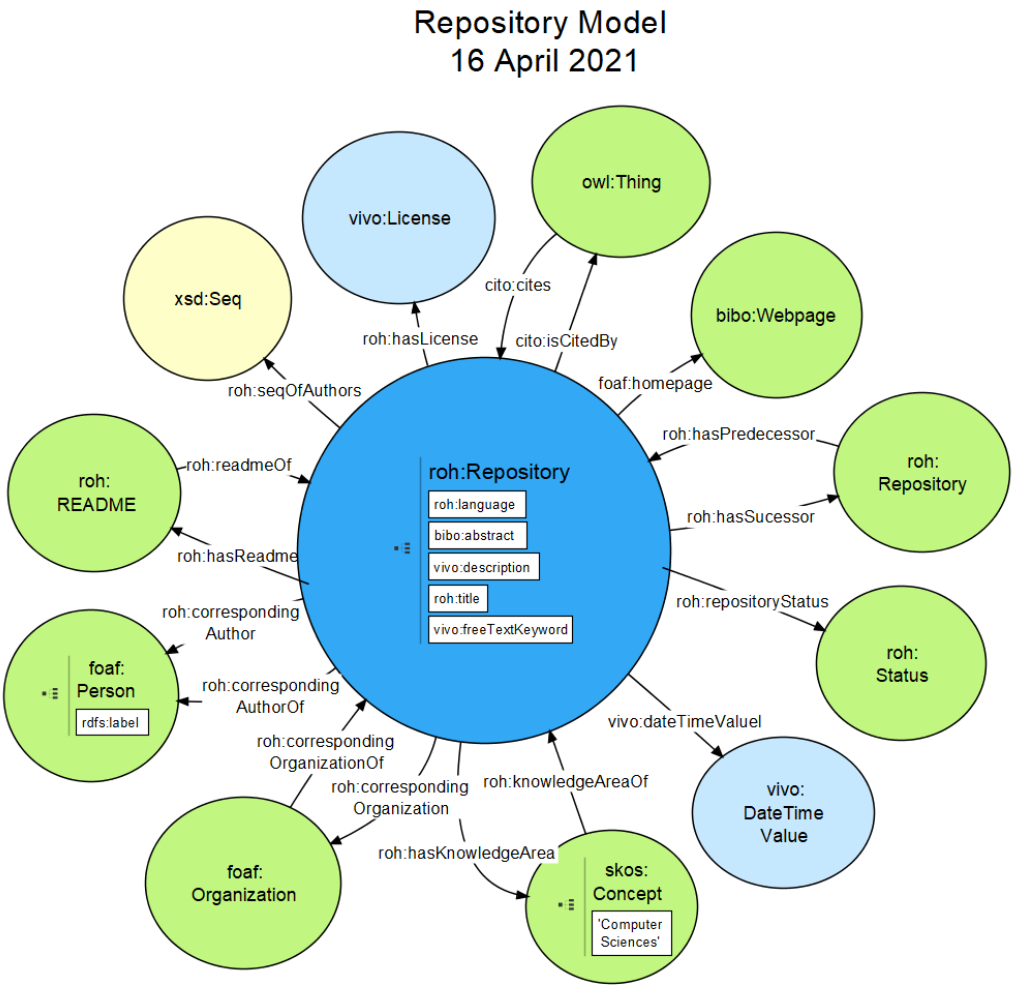

Figure 8. Ontological diagram for `Repository`.

1.7.2. roh:ExperimentalProtocol Entity

The `roh:ExperimentalProtocol` entity (see Figure 9), new in ROH, models the process or protocol to perform an experiment. The `roh:ExperimentalProtocol` entity may be linked to the `roh:ExperimentalProtocolResult` entity, a document that exposes the result of carrying out this process with some concrete data, through `roh:produces`.

The following table illustrates the object and data properties associated to entity `roh:ExperimentalProtocol`.

Prefix	Class	Prefix	**Object property** (bold indicates explicit Domain, otherwise a Restriction)	Range Class	Prefix	**Datatype Property** (bold indicates explicit domain; otherwise a restriction)	**Range Datatype** (if typed)	Range values
Roh	ExperimentalProtocol	roh	correspondingAuthor	foaf:Person	roh	language	xsd:string	
		roh	hasKnowledgeArea	(skos:Concept and (skos:inScheme some roh:KnowledgeArea))	vivo	description	xsd:string	
		roh	produces	roh:ExperimentalProtocolResult	bibo	abstract	xsd:string	
		cito	cites	roh:ExperimentalProtocol or ero:ERO_0000071 or roh:Repository or bibo:Document	vivo	freeTextKeyword	xsd:string	
		roh	partOfResearchResult	roh:ResearchResult	roh	title	xsd:string	
		rog	partOfRepository	roh: Repository				
		roh	hasPredecessor	roh:ExperimentalProtocol				
		roh	seqOfAuthors	rdf:Seq				
		roh	hasLicense	vivo:License				
		vivo	dateTimeValue	vivo:DateTimeValue				
		foaf	homePage	vivo:Webpage				

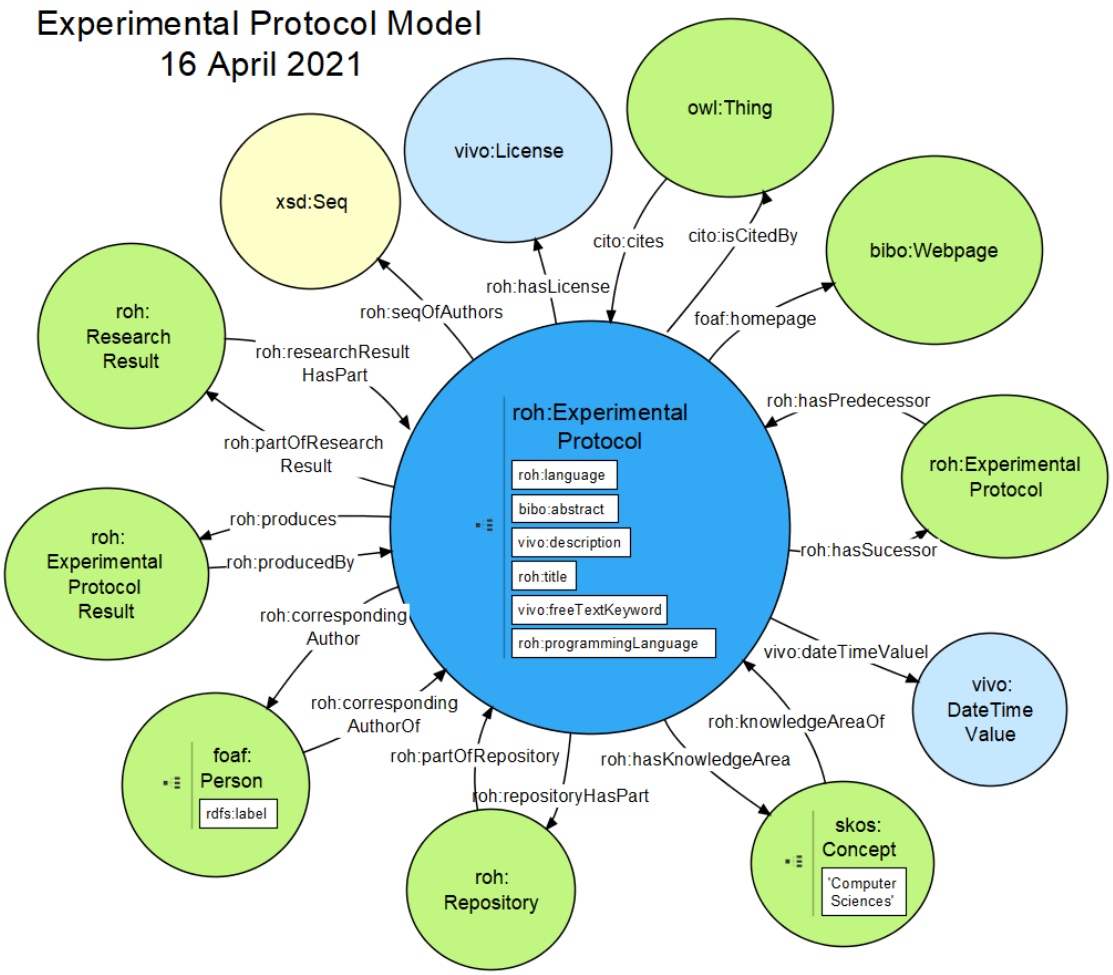

Figure 9. Ontological diagram for `Experimental Protocol`.

1.7.3. obo-ero:ERO_0000071 (Software) Entity

The `software` entity is imported from the obo-ero ontology. Software is associated through `roh:hasSucessor` with another `roh:software` when the latter is based on the first one, and through `roh:hasReadme` with the document describing the software `roh:README`. The programming language for a software is expressed through data property `roh:programmingLanguage`.

The following table illustrates the object and data properties associated to `obo-ero:ERO_0000071 (Software)`.

Prefix	Class	Prefix	**Object property** (bold indicates explicit Domain, otherwise a Restriction)	Range Class	Prefix	**Datatype Property** (bold indicates explicit domain; otherwise a restriction)	**Range Datatype** (if typed)	**Range values**
ero	ERO_0000071	roh	correspondingAuthor	foaf:Person	roh	language	xsd:string	
		roh	hasKnowledgeArea	(skos:Concept and (skos:inScheme some roh:KnowledgeArea))	vivo	description	xsd:string	
		roh	hasReadme	roh:README	bibo	abstract	xsd:string	
		cito	cites	roh:ExperimentalProtocol or ero:ERO_0000071 or roh:Repository or bibo:Document	vivo	freeTextKeyword	xsd:string	
		roh	partOfResearchResult	roh:ResearchResult	roh	title	xsd:string	
		roh	partOfRepository	roh:Repository				
		roh	hasPredecessor	ero:ERO_0000071	roh	programmingLanguage	xsd:string	
		roh	seqOfAuthors	rdf:Seq				
		roh	hasLicense	vivo:License				
		roh	softwareStatus	roh:Final or roh:Provisional				
		vivo	dateTimeValue	vivo:DateTimeValue				
		foaf	homePage	vivo:Webpage				
	roh ReservableSoftware							

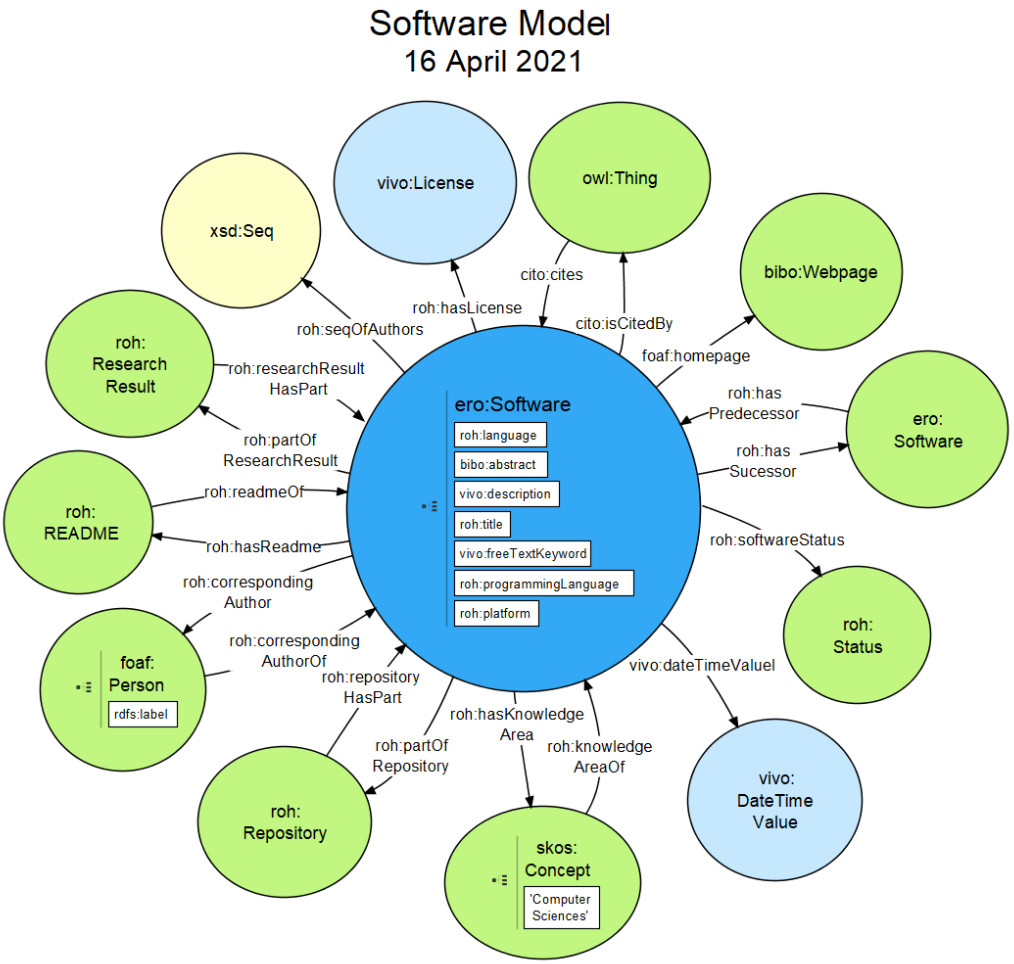

Figure 10. Ontological diagram for `Software`.

1.8. Activity entity

The entity research activity (`roh:Activity`), new in ROH and visualized in **¡Error! No se ncuentra el origen de la referencia.**, represents the activities in which People participate (`roh:participes`) and organized by Organizations (`foaf:Organization`) reflected through the `roh:hasRole` relationship that connects with the intermediary entity `vivo:OrganizerRole`. Each activity is usually linked to a project through the relationship (`roh:participes`) and causes a project expenditure linked through (`vivo:relates`). A detailed hierarchy of activity subtypes is defined below `roh:Activity`: `bibo:Conference`, `vivo:Course`, `vivo:Internship` or `roh:ThesisViva`.

Related to Activity, it is also important to describe `roh:Expense`, which denotes the expenses incurred either by a project (`vivo:Project`) or person (`foaf:Person`) and linked through `roh:spends`. Every expense has a time instant of associated expense (`vivo:DateTimeValue`) and other properties that qualify it as (`roh:monetaryAmount`, `roh:currency`, `roh:title` or `vivo:description`. The following subclasses of `roh:Expense` have been defined: `roh:PatentExpense`, `roh:PesonExpense`, `roh:ProjectExpense` and `roh:ResearchObjectExpense`. Besides, each expense can have associated a different type of expense through `roh:hasExpenseClassification` (Congress/network, external recruitment, Investment/inventory, office, other costs, publication, representation or staff expenses).

The following table illustrates the class hierarchy, object and data properties defined by roh:Activity.

Prefix	Class		Prefix	**Object property** (bold indicates explicit Domain, otherwise a Restriction)	Range Class	Prefix	**Datatype Property** (bold indicates explicit domain; otherwise a restriction)	**Range Datatype** (if typed)	Range values
roh	**Activity**		roh	hasContactInfo	vcard:Kind	vivo	identifier	xsd:string	
			vivo	hasKnowledgeArea	skos:Concept	roh	description	xsd:string	
			roh	**participatedBy**	foaf:Agent or vivo:Project	vivo	freeTextKeyword	xsd:string	
			bibo	presents	bibo:Document	roh	title	xsd:string	
			vivo	relates	roh:Expense or obo-bfo:BFO_0000023 (Role)				
			vivo	dateTimeInterval	vivo:DateTimeInterval				
			gn	locatedIn	gn:Feature				
	vivo	Competition							
	bibo	Conference				vivo	abbreviation	rdfs:Literal	
	vivo	Course	obo-ro	partOf	vivo:AcademicDegree	vivo	**courseCredits**	xsd:int	
						vivo	**courseHours**	xsd:string	
	vivo	Exhibit							
	bibo	Hearing							
	vivo	Internship							
	vivo	Interview							
	vivo	Meeting							
	bibo	Performance							
	vivo	Presentation							
	vivo	InvitedTalk							
	roh	PanelTalk							
	roh	ThesisViva							
	bibo	Workshop							

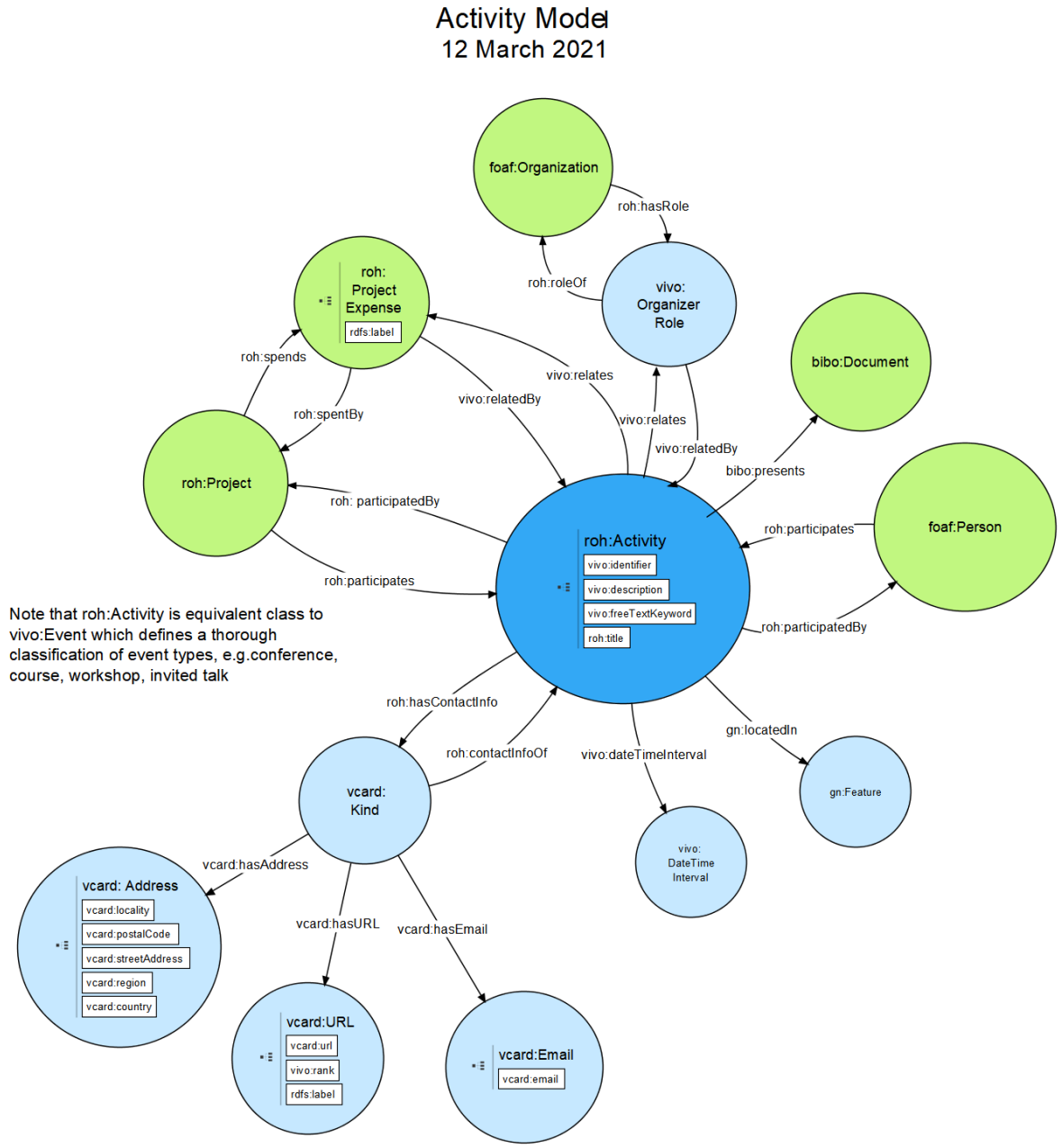

Figure 11. Ontological diagram for entity `Activity`.

1.9. Other entities in ROH

For more details on other entities in ROH check the tables detailing class hierarchies, object and data properties for all entities defined in ROH at the following PDF file: https://github.com/HerculesCRUE/ROH/blob/gh-pages/1-%20OntologyDocumentation.pdf.

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