

FONDO EUROPEO DE DESARROLLO REGIONAL (FEDER)

Una manera de hacer Europa

Bilbao, Marzo de 2021

ONTOLOGY DOCUMENTATION

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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 (ERO)	Creative Commons Attribution License 4.0	https://open.catalyst.harvard.edu/wiki/display/eaglei/Ontology
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 Hércules	Creative Commons Attribution License 4.0	http://purl.org/roh

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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	Oa The Web Annotation Data Model	Creative Commons Attribution License 4.0	http://www.w3.org/ns/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.

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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).

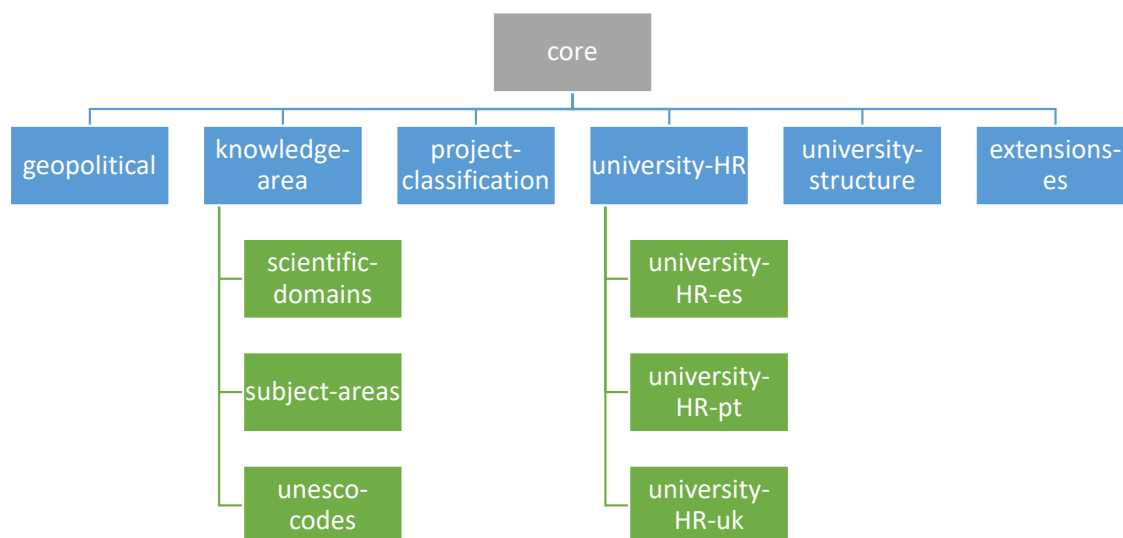


Figura 2. Hierarchical module structure of ROH network of ontologies.

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`.

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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:KnowledgeArea` 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:HRClassification`. 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`

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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 a 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`:

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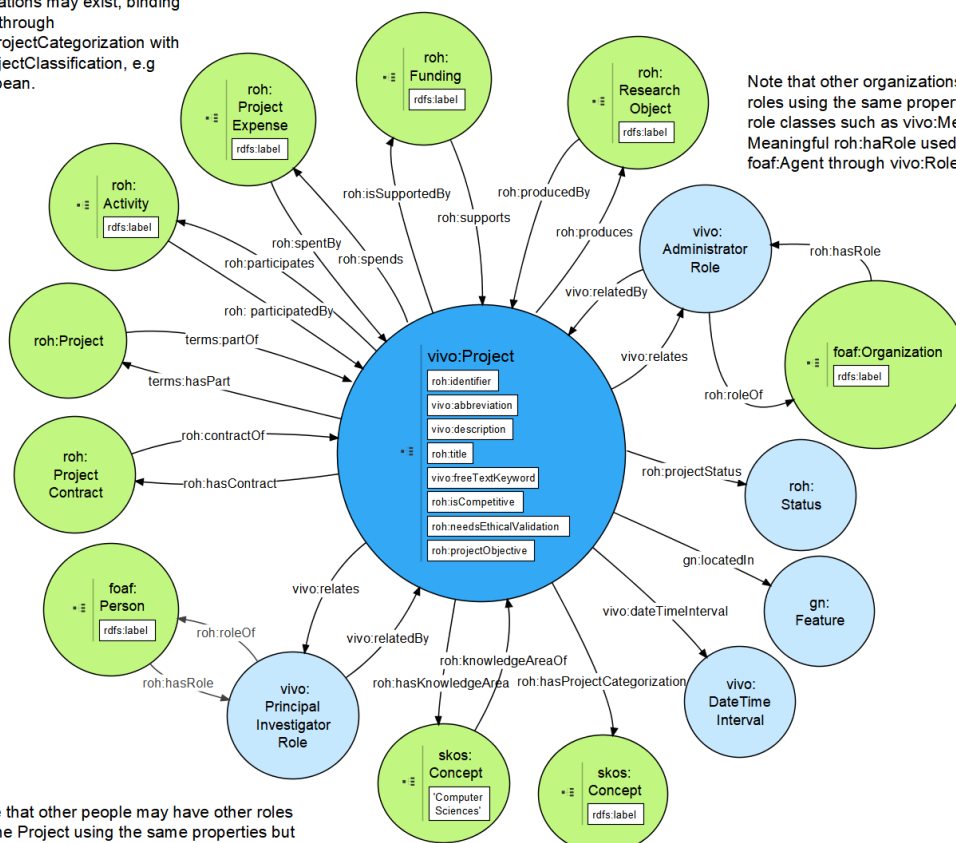
Prefix	Class	Prefix	Object property (bold indicates explicit Domain, otherwise a Restriction)	Range Class	Prefix	Datatype Property (bold indicates explicit domain; otherwise a restriction)	Range Datatype (if typed)	Range values
vivo	Project	roh	hasKnowledgeArea	skos:Concept and (skos:inScheme some roh:Knowledge 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				

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Project Model 12 March 2021

Notice that different Projects categorizations may exist, binding a project through `roh:hasProjectClassification` with a `roh:ProjectClassification`, e.g. `roh:European`.



Note that other organizations may have other roles using the same properties but different role classes such as `vivo:MemberRole`. Meaningful `roh:haRole` used to link `foaf:Agent` through `vivo:Role` with `vivo:Project`

Note that other people may have other roles on the Project using the same properties but different role classes such as `vivo:CoPrincipal InvestigatorRole` and `vivo:InvestigatorRole`

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

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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.

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- `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` subclasses 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 subclasses like `roh:MasterThesis` or `roh:PhDThesis`.

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

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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"}

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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:AccreditationIssuer` 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`.

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- `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`.

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

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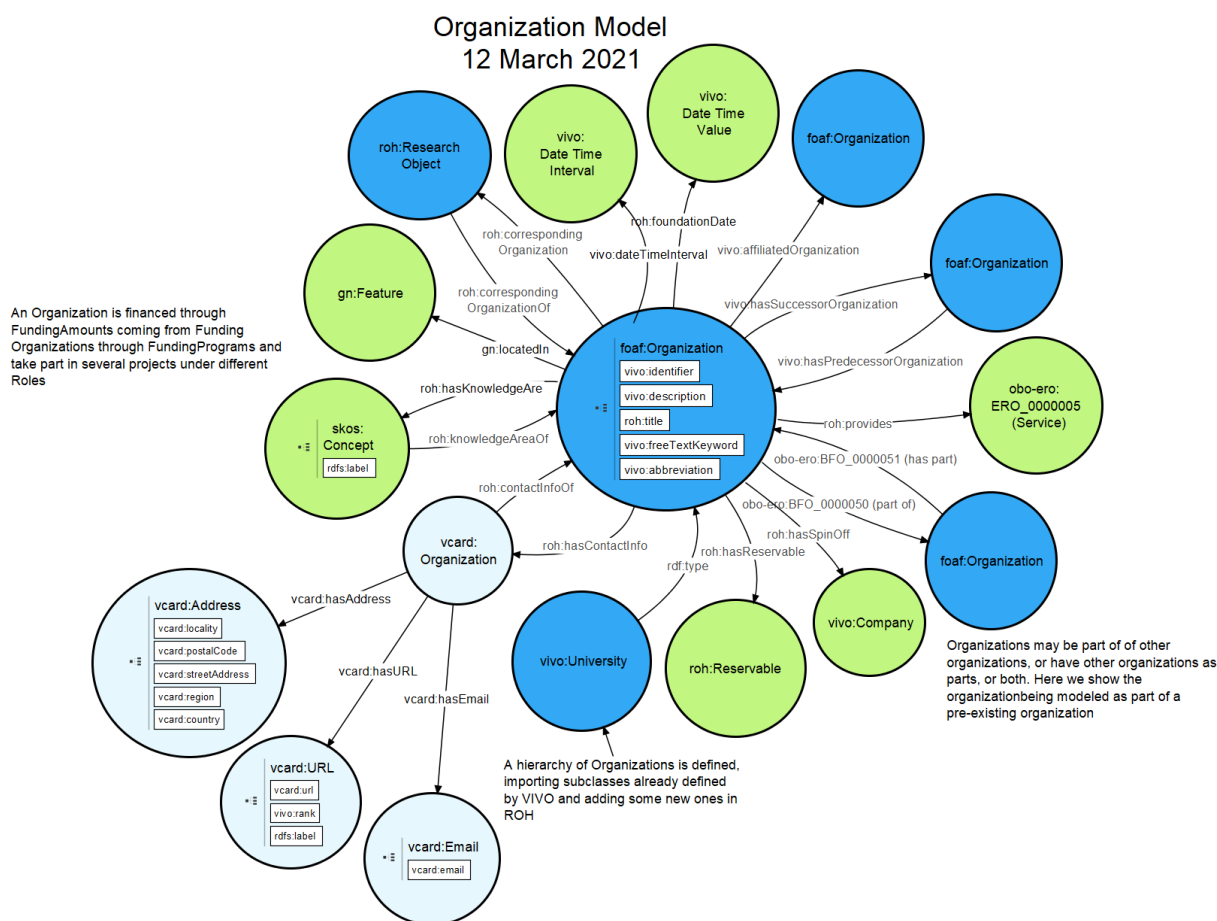


Figura 5. Ontological diagram for entity Organization.

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`.

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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:FundingAmounts` through object property `obo-ro:BFO_0000051` (has part). A `roh:FundingProgram` funds (`roh:funds`) a `roh:Funding`, funding programs are promoted by `roh:FundingOrganizations`. Notice that a `roh:Funding` is divided into several `roh:FundingAmounts` associated with different `foaf:Organizations` 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.

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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	monetaryAmount	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				

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There are several subclasses of Funding that allow to classify Funding into Grant, Loan, Agreement. Data property `roh:publicFunding` to indicate public or private nature.

The diagram illustrates an ontology for funding and organizations. Key classes and their relationships include:

- roh:Funding** (blue circle) is the central class, with subclasses **roh:Funding Program** and **roh:Funding Source** (both green circles). It has properties like `vivo:identifier`, `vivo:description`, `vivo:freeTextKeyword`, and `roh:publicFunding`.
- roh:Funding Amount** (blue circle) is a subclass of **roh:Funding**, with properties `vivo:identifier`, `roh:monetaryAmount`, and `roh:currency`.
- vivo:Funding Organization** (green circle) is a subclass of **roh:Funding Source**, with properties like `roh:promotes` and `roh:isPromotedBy`.
- vivo:Role** (light blue circle) is a subclass of **roh:Funding**, with properties like `roh:roleOf` and `roh:hasRole`.
- foaf:Organization** (green circle) is a subclass of **vivo:Funding Organization**, with properties like `roh:grants` and `roh:isGrantedBy`.
- gn:Feature** (light blue circle) is a subclass of **roh:Funding Program**, with property `roh:hasFundingProgram`.
- vcards** (light blue circles) include **vcards:Address**, **vcards:Kind**, **vcards:URL**, **vcards:Email**, and **vcards:Geo**, with properties like `vcards:hasAddress`, `vcards:hasURL`, `vcards:hasEmail`, and `vcards:hasGeo`.
- vivo:Date Time Interval** (green circle) is a subclass of **roh:Funding**, with property `roh:funds`.

Additional text boxes provide context:

- skos:Concept** (green circle) is a subclass of **roh:Funding Program**, with property `rdfs:label`.
- obo-ro:BFO_0000051 (has part)** and **obo-ro:BFO_0000050 (part of)** are relationships between **roh:Funding** and **roh:Funding Amount**.
- A Funding is divided into several FundingAmounts, each for a year (complete or the months within that year) and associated to an organization** (green circle) is a note about the relationship between **roh:Funding** and **roh:Funding Amount**.
- An Organization is financed through FundingAmounts corresponding to a Funding coming from a FundingSource promoted by Funding Organizations through Funding Program. An Organization can take part in several projects under different roles.** (green circle) is a note about the relationship between **foaf:Organization** and **roh:Funding Amount**.
- Expressed as a geo uri "geo:25.094190,102.772167"** (green circle) is a note about the **vcards:Geo** class.

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

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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. Furthermore, the object property `vivo:relates` can be used to organize Research Objects that are inside of the Research Result. For example, if the researcher thinks one Research Object is the main link between all Research Objects contained in the Research Result, he/she can relate this Research Object with the rest with the `vivo:relates` object property. In this manner, the researcher can organize the Research Object inside the Research Result.

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.

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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 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	spends	roh:RsearchObjectExpense				
		bibo	aauthorList	rdd:Seq				
		roh	hasLicense	vivo:License				
roh	ResearchObject ¹	roh	correspondingOrganization	foaf:Organization	roh	language	xsd:string	
		roh	hasPartOfResearchResult	roh:ResearchResult				
		roh	producedBy	roh:Project				
		vivo	relates					

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

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`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
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	hasSuccessor	roh:ResearchResult	vivo	description	rdfs:Literal	
		roh	correspondingAuthor	foaf:Person	vivo	freeTextKeyword	xsd:string	
		vivo	dateTimeInterval	vivo:DateTimeInterval	roh	needsEthicalValidation	xsd:boolean	
roh	ResearchObject ³	roh	correspondingOrganization	foaf:Organization	roh	language	xsd:string	
		roh	hasPartOfResearchResult	roh:ResearchResult				
		roh	producedBy	roh:Project				

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Pref ix	Class	Pref ix	Object property (bold indicates explicit Domain, otherwise a Restriction)	Range Class	Pref ix	Datatype Property (bold indicates explicit domain; otherwise a restriction)	Range Datatype (if typed)	Range values
obo-lao	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-lao:IAO_0000013 (Journal Article)	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							

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		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	Proforma Invoice						
		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	Research Proposal	vivo	relates	roh:Justification or roh:ProjectContract or roh:Project or vivo:ResearchProposal				
		roh	Technical Report							
		bibo	Thesis	roh	supervisedBy	foaf:Person	vivo	abbreviation	rdfs:Literal	
							vivo	placeOfPublication	rdfs:Literal	
		roh	Bachelors Thesis							
		roh	Masters Thesis							
		roh	PhD Thesis							
		bibo	Webpage							

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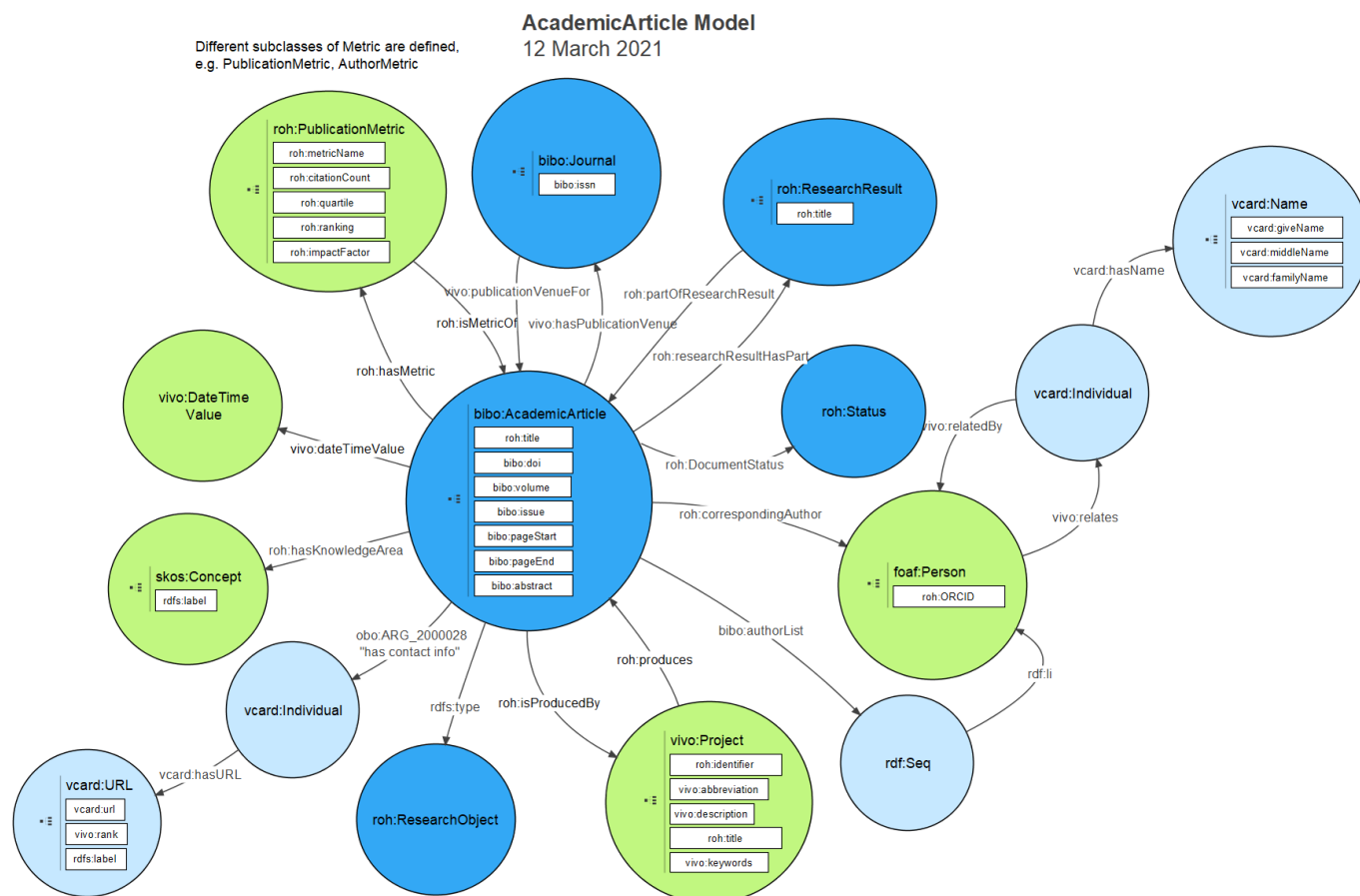


Figure 7. Ontological diagram for AcademicArticle.

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.

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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).

Pref ix	Class	Pref ix	Object property (bold indicates explicit Domain, otherwise a Restriction)	Range Class	Pref ix	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	

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Repository Model 16 April 2021

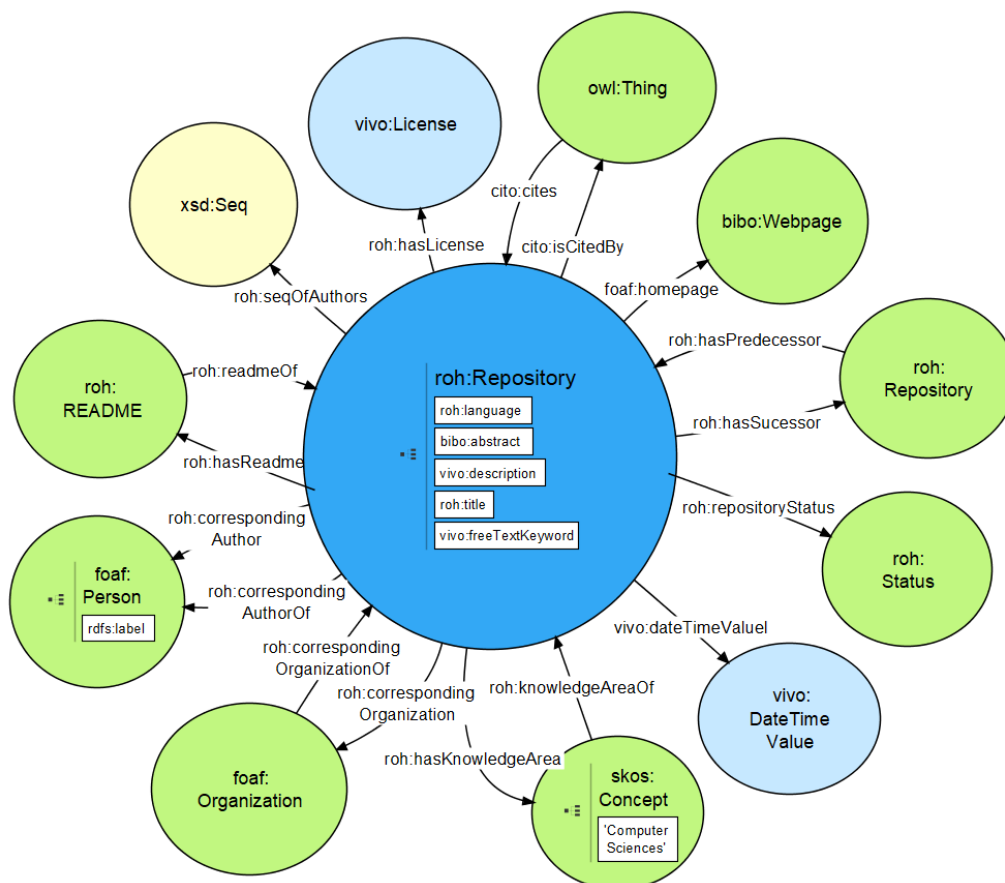


Figure 8. Ontological diagram for Repository.

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`.

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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				

Experimental Protocol Model

16 April 2021

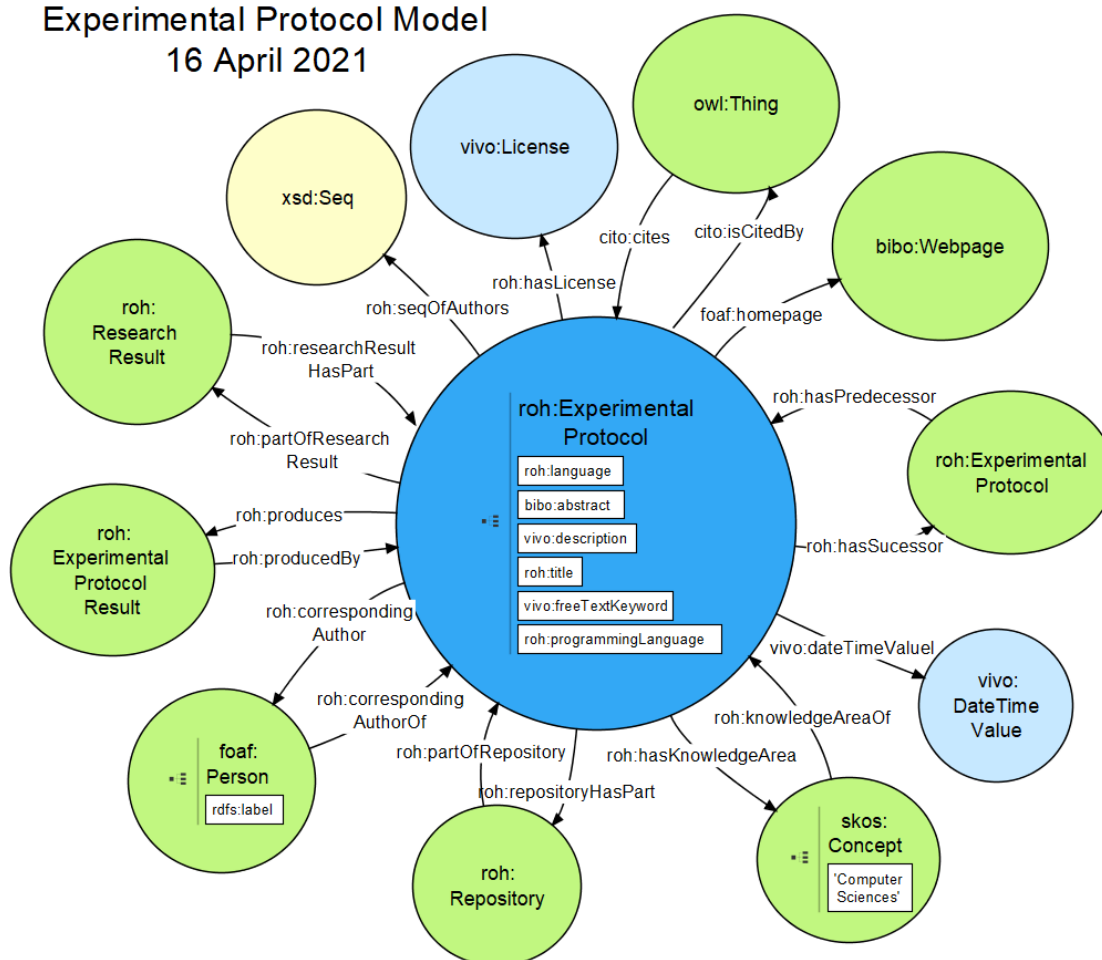


Figure 9. Ontological diagram for Experimental Protocol.

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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						

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Software Model
16 April 2021

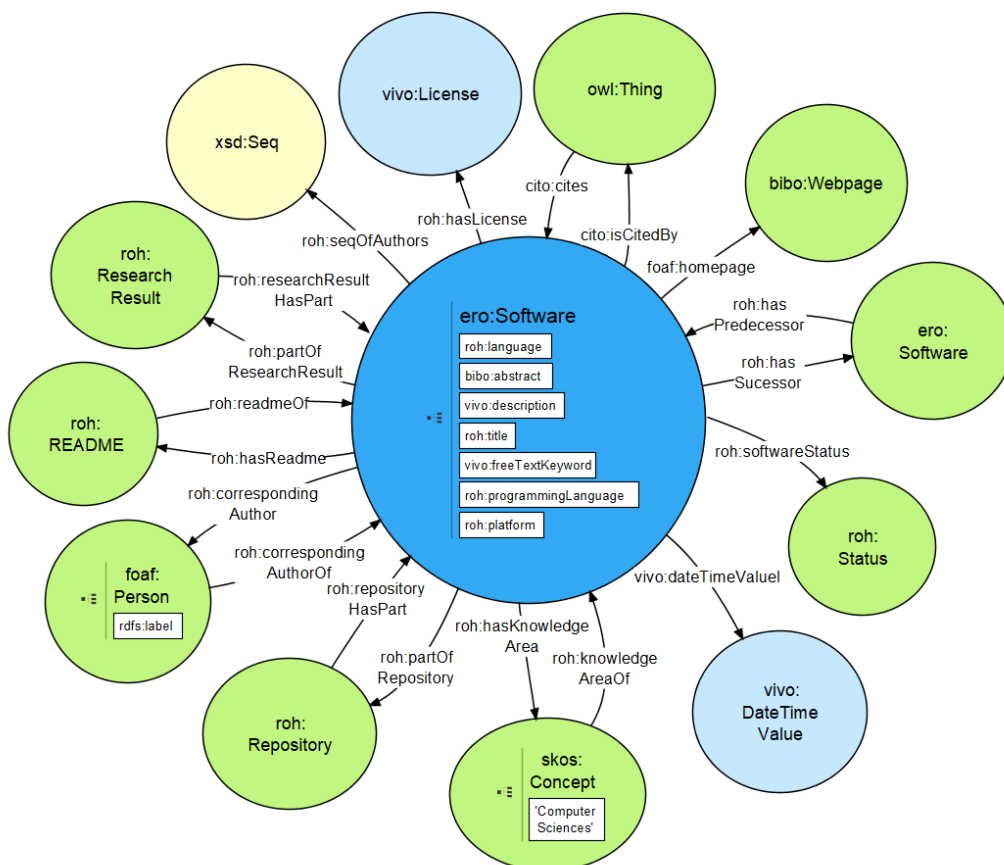


Figure 10. Ontological diagram for Software.

1.8. Activity entity

The entity research activity (`roh:Activity`), new in ROH and visualized in **Error! No se encuentra 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`.

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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:PersonExpense`, `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`.

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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	vcad: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: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							

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Activity Model
12 March 2021

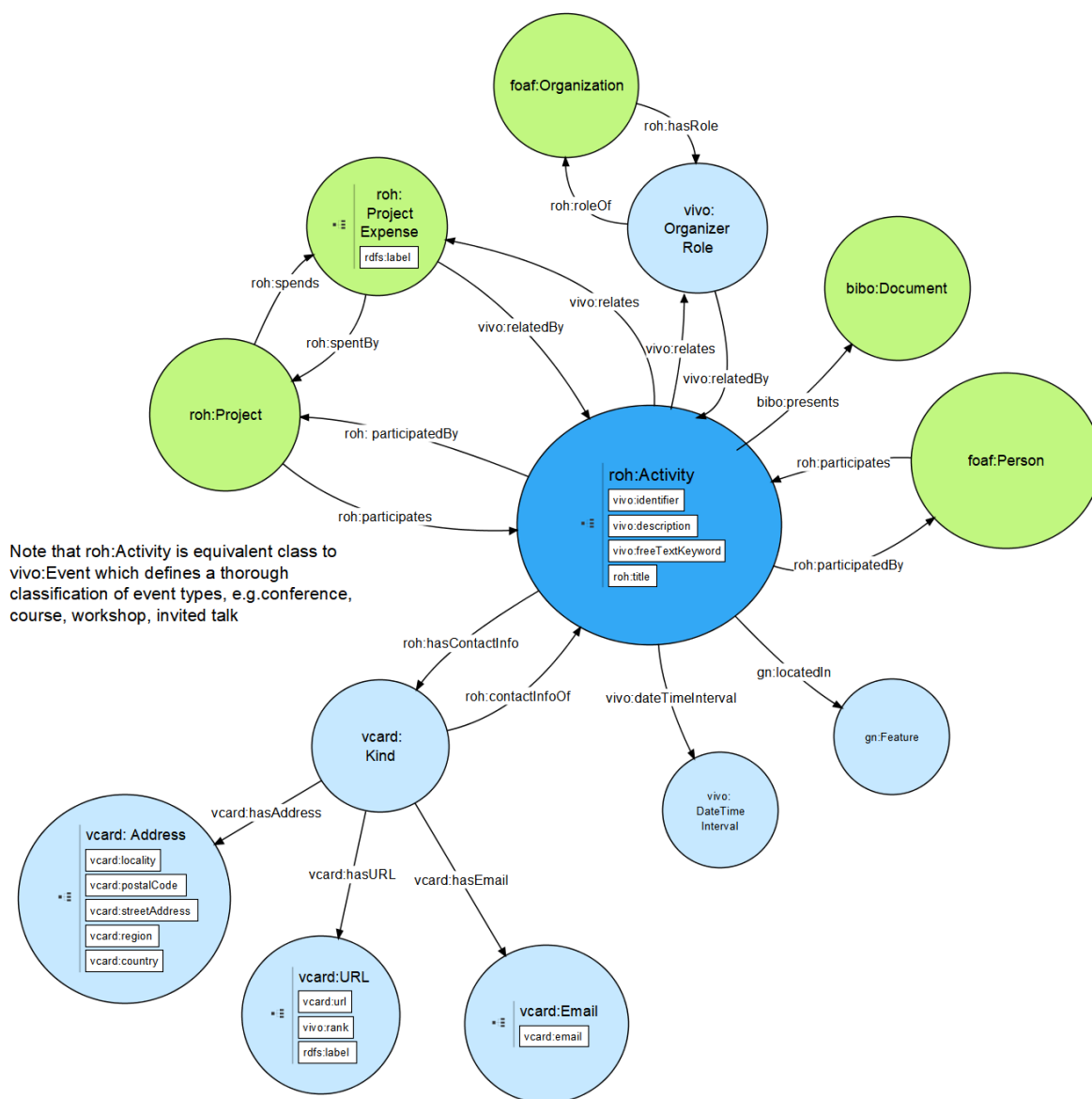


Figure 11. Ontological diagram for entity Activity.

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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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