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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	Creative Commons Attribution License 4.0	https://open.catalyst.harvard.edu/wiki/display/eaglei/Ontology

	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#

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.

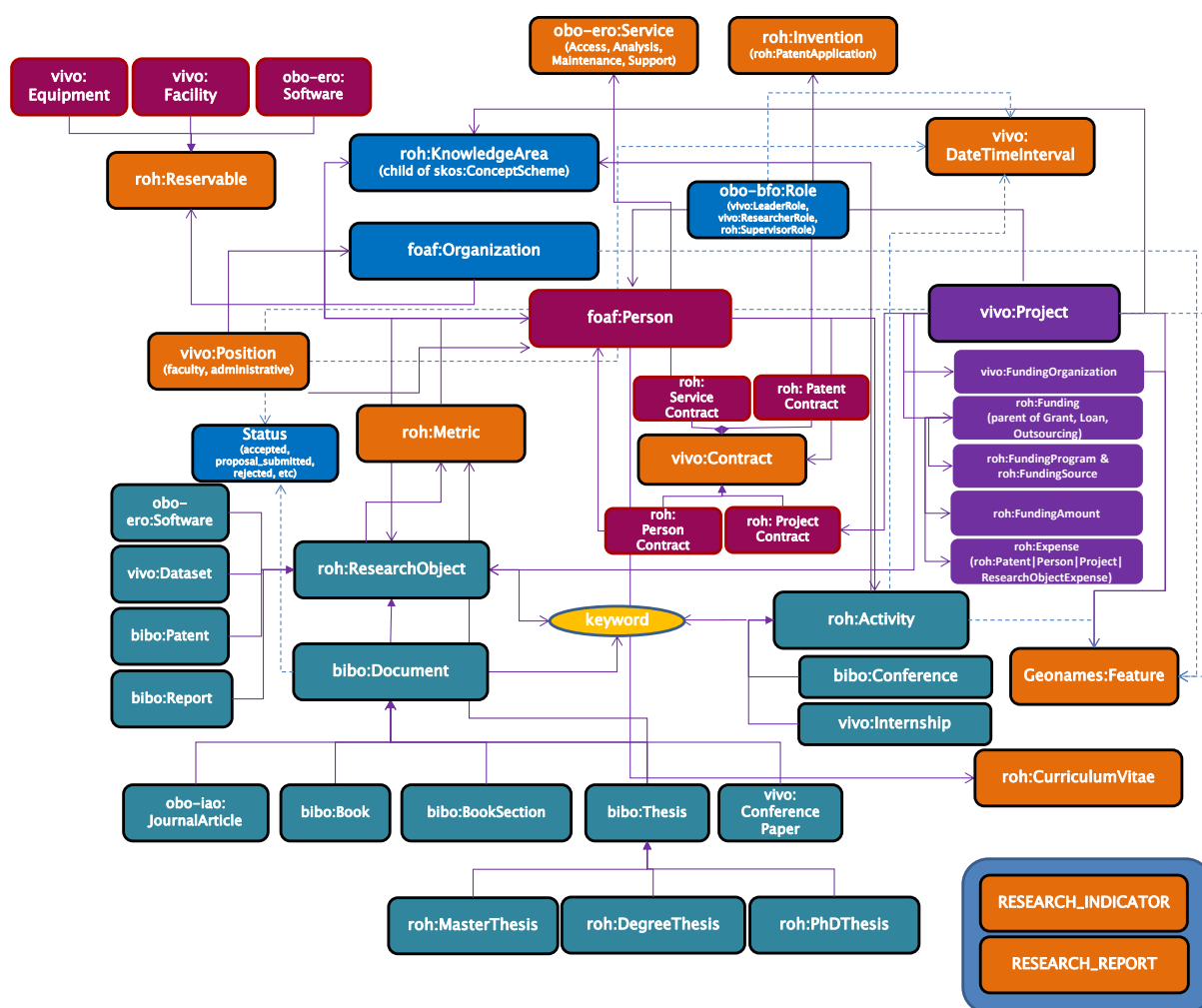


Figura 1. High level diagram of ROH –Red de Ontologías Hércules.

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).

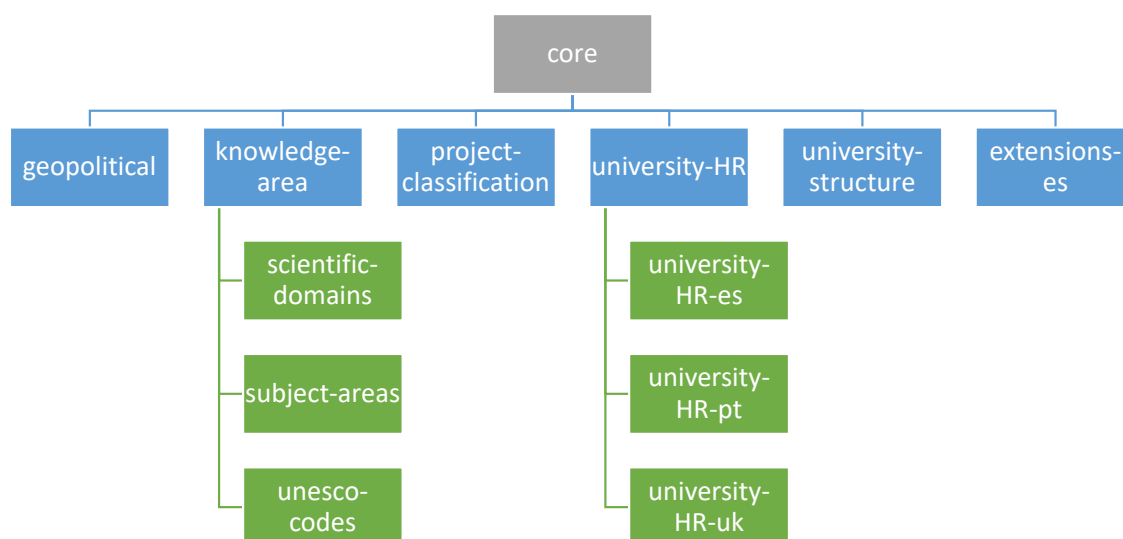


Figura 2. Hierarchical module structure of ROH network of ontologies.

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:HumanResourceClassification`. 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).

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- `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`:

FONDO EUROPEO DE DESARROLLO REGIONAL (FEDER)

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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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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.

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- `bibo:Document`, where a researcher through `bibo:authorList` is participating in a `bibo:Document` as one of its authors.
- `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")



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:Accreditation` (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:Activity`, has several instances of attribute `vivo:keyword`, 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`.

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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: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 necessarily 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: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)

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

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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	vcad: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	foundationDate	vivo:DateTimeValue	roh	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	foaf:Document				
		roh	ownerOrganizationOf	roh:Patent Application 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	roh	issues	roh:Accreditation			
	vivo	Center						
	vivo	Company	roh	hasCompanyClassification	(skos:Concept and (skos:inScheme some roh:KnowledgeArea))	roh	isStartup	xsd:boolean
			roh	isSpinoffOf	foaf:Organization	roh	publicCompany	xsd:boolean
		roh	LargeEnterprise					
		roh	MediumEnterprise					
		roh	MicroEnterprise					
		roh	SmallEnterprise					
	vivo	Consortium						
	vivo	Department						
	roh	EthicsCommittee	roh	produces	roh:EthicalReport			
	vivo	Foundation						
	roh	FundingOrganization	roh	promotes	roh:FundingProgram or roh:FundingSource			
	vivo	GovernmentAgency						
	vivo	Institute						
	roh	ManagementInstitute						
	roh	ResearchGroup				roh	excellenceLabel	xsd:boolean
	vivo	University	roh	awards	vivo:AwardedDegree			
	roh	Company	roh	hasCompanyCategorization	roh:CompanyClassification	roh	isStartup	xsd:boolean
						roh	publicCompany	xsd:boolean

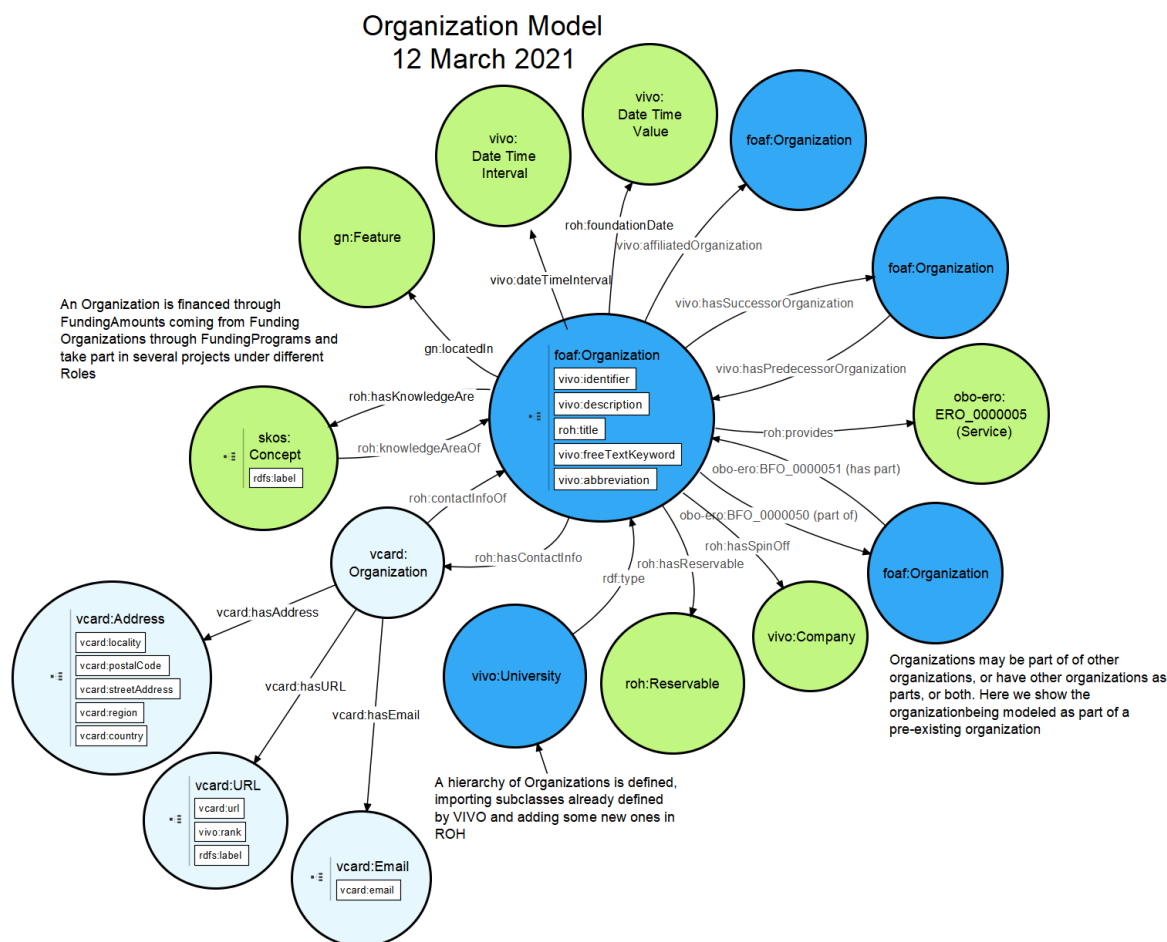


Figura 5. Ontological diagram for entity Organization.

1.6. Funding entity

The `roh:Funding` entity (see Figura 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 Figura 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 Figura 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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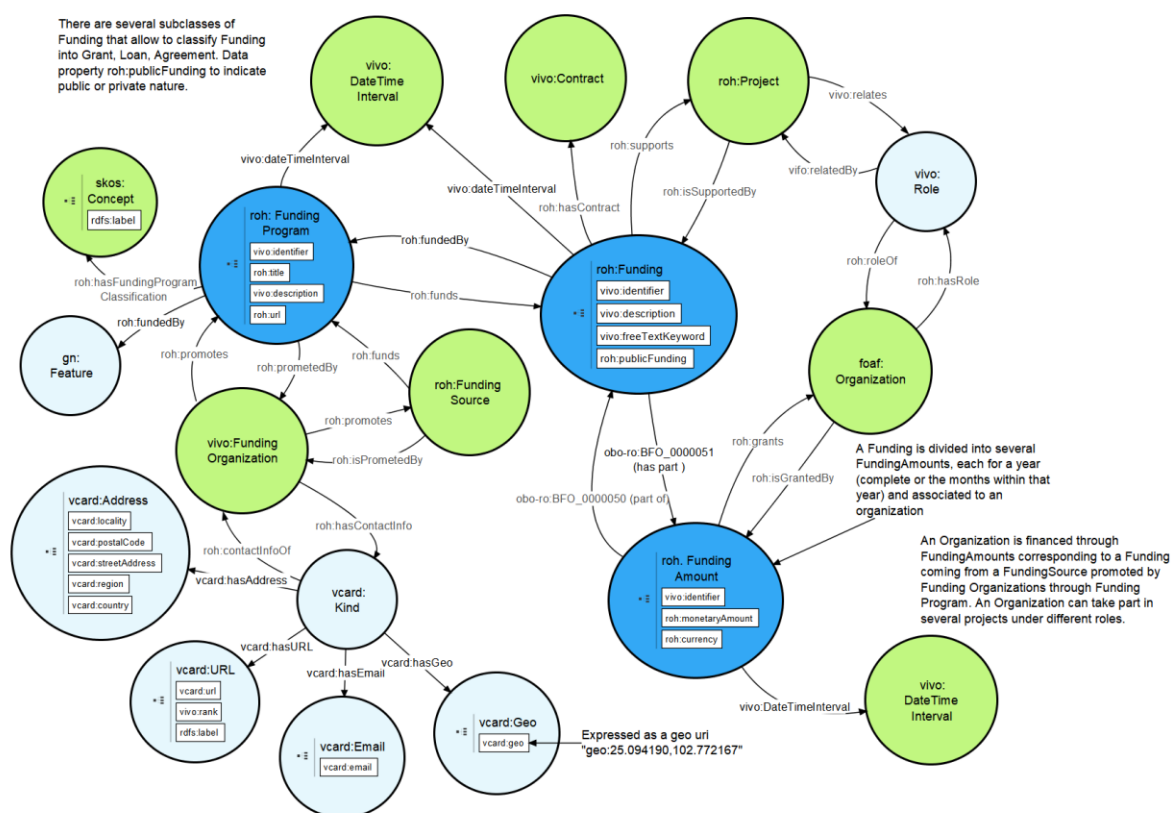


Figura 6. Ontological diagram for `Funding`.

1.7. Research Object Entity

The research object entity (`roh:ResearchObject`) is a new entity defined in ROH (see Figure 7) that corresponds to a research result generated by a person (researcher), usually through work on a project. Notice that `roh:ResearchObject` is a defined class, which follows these restrictions:

```
(( (roh:correspondingAuthor some foaf:Person) and
(roh:hasKnowledgeArea some
(skos:Concept and (skos:inScheme some roh:KnowledgeArea)))) and
(roh:correspondingAuthor only foaf:Person) and (roh:hasKnowledgeArea
only
(skos:Concept and (skos:inScheme some roh:KnowledgeArea)))) or
(roh:producedBy only roh:Project).
```

This is, an instance in ROH belongs to class `roh:ResearchObject` if it meets these restrictions.

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A research object has been modelled around entity `obo-iao: IAO_0000030` (Information Content Entity). Such entity is linked to at least one `foaf:Person` through object property `roh:correspondingAuthor`. In the case of its subclass `bibo:Document`, the contributors of a research object are accessible through object property `bibo:authorList`. Usually a `roh:ResearchObject` results from working on a `vivo:Project` (`roh:produces`). Under `obo-iao: IAO_0000030` (Information Content Entity) entity a complete taxonomy of research objects mostly imported from BIBO [4], covering all kinds of publications, patents, software 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 primary author of a research object is accessible through the `roh:correspondingAuthor` property. 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.

The most important research result is represented by the concept publication 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 `roh:ResearchProject` 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 hand `roh:Dossier` represents a collection of reports related to a `vivo:Project`, which may include all the types of reports above mentioned.

The below table shows the data and object properties, as well as subclasses, of entity `roh:ResearchObject`.

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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	ResearchObject	roh	hasKnowledgeArea	(skos:Concept and (skos:inScheme some roh:KnowledgeArea))				
		roh	correspondingAuthor	foaf:Person				
		roh	producedBy	roh: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
obo-lao	IAO_0000030 (Information Content Entity)	roh	correspondingOrganization	foaf:Organization				
	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							

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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
obo-iao	IAO_0000030 (Information Content Entity)	roh	correspondingOrganization	foaf:Organization				
	bibo Document	bibo	authorList	rdf:Seq	bibo	abstract	xsd:string	
		roh	correspondingAuthor	foaf:Person	bibo	doi	xsd:string	
		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				
		roh	documentStatus	roh:Accepted or roh:Rejected	roh	title	xsd:string	
	vivo Abstract							
	bibo Article				bibo	issue		
	bibo AcademicArticle	vivo	hasPublicationVenue	bibo:Journal	bibo	eanucc13	rdfs:Literal	
	obo-iao:IAO_0000013 (JournalArticle)	vivo	dateIssued	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				

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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
obo-iao	IAO_0000030 (Information Content Entity)	roh	correspondingOrganization	foaf:Organization				
	bibo Document	bibo	authorList	rdf:Seq	bibo	abstract	xsd:string	
	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							

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The entity research activity (`roh:Activity`), new in ROH and visualized in Figura 8, 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: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.

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						

Activity Model
12 March 2021

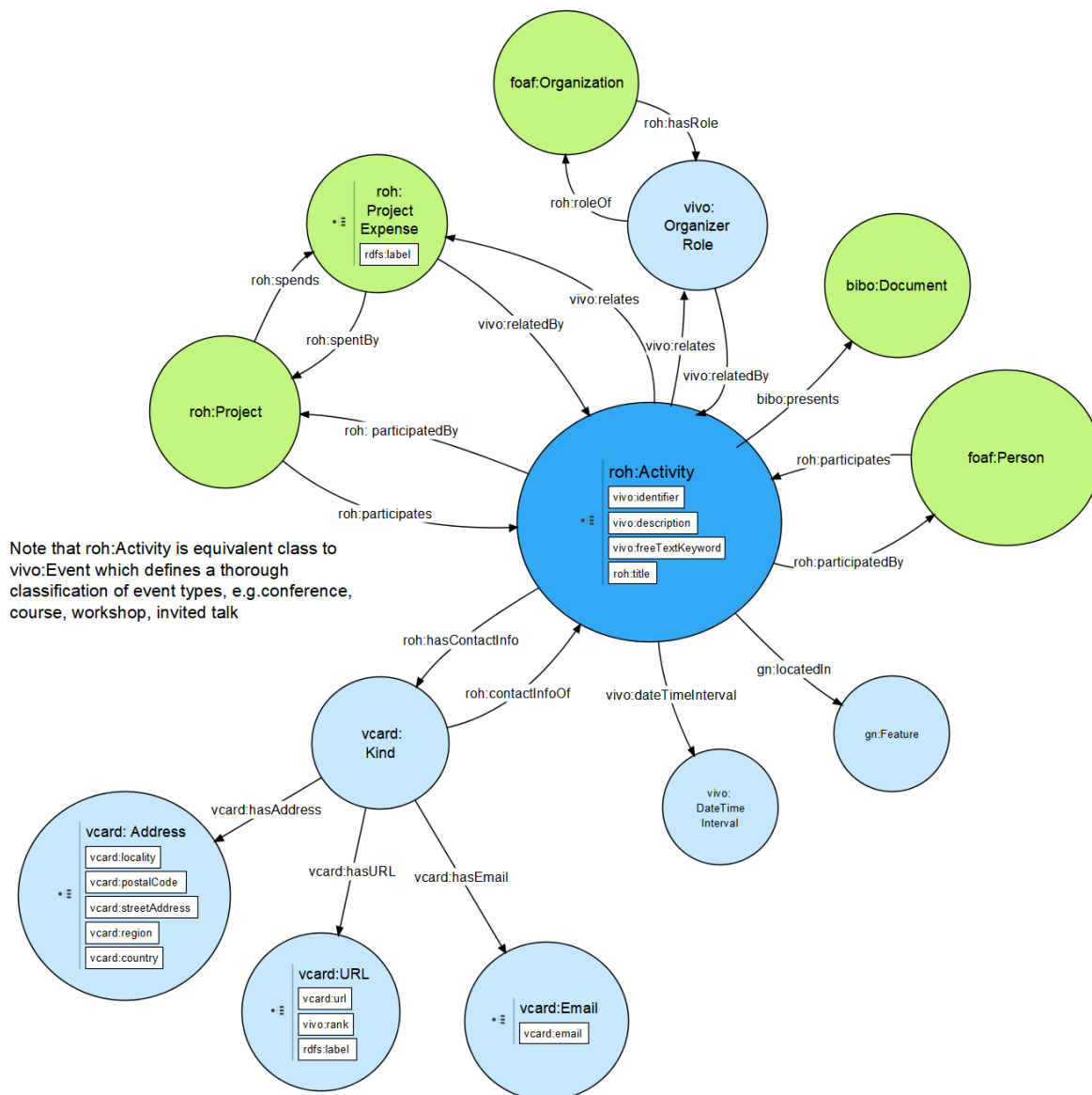


Figura 8. Ontological diagram for entity Activity.

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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