DINGO: an ontology for projects and grants linked data

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Abstract. We present DINGO (Data INtegration for Grants Ontology), an ontology that provides a machine readable extensible framework to model data relative to projects, funding, actors, and, notably, funding policies in the research landscape. DINGO is designed to yield high modeling power and elasticity to cope with the huge variety in funding, research and policy practices, which makes it applicable also to other areas besides research where funding is an important aspect. We discuss its main features, the principles followed for its development, its community uptake, its maintenance and evolution.

Keywords: ontology · linked data, research funding, research projects, research policies

1 Introduction, Motivation, Goals and Idea

Services and resources built around Semantic Web and linked (open) data technologies have been increasingly impacting research and research-related activities in the last years. Development has been intense along several directions, for instance in "semantic publishing" [36], but also in the aspects directed toward the reproducibility and attribution of research and scholarly outputs, leading also to the interest in having Open Science Graphs interconnected at the global level [21]. All this has become more and more essential to research practices, also in light of the so-called reproducibility crisis affecting a number of research fields (see, for instance, the huge list of latest studies at *https://reproduciblescience.org/2019*).

In fact, the demand of easily and automatically parsable, interoperable and processable data goes beyond the purely academic sphere. The research landscape comprises a vast number and type of activities, with multiple and diverse stakeholders, actors and with impact on several aspects and sectors of society. One aspect of huge relevance is the funding of research, together with the related policies for science development and sustainability.

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Machine-actionable, inter-operable data is in huge demand in those respects. On the one hand, for instance, research funding agencies face increasing pressure to report on impact derived from their activities. This has to be seen in a broader context of the increased role that research assessment play in research policy debates. On the other hand, researchers and research organisations are asked more and more to conform to policy specifications in order to obtain and secure their funding. The compliance to funding and research polices is also part of the wider debate about best research practices such as Open Science, Open Access, FAIR data and sustainable research.

Research assessment and compliance verification at any level involves collection, management and analysis of a great increasing deal of data of different types and from multiple sources . The classical way to meet this demand has been to collect data directly from various research actors. This increases the burden on researchers, university administration and funding agencies, as those data has to be managed and curated. Moreover, the information, typically collected in an “ad hoc” way and in isolation, is not available to others. This results also in duplication of efforts, due to the necessity to re-do the linking and processing of data. The difficulty of data linking and semantic interpretation across different realities and agencies also entails that data and analysis are of limited value when it comes to put them in broader perspective.

Solving these problems entails having data that can be easily parsed, processed and interpreted computationally. This requires expressive shared machine-processable descriptions and models on the Web. Technologies as RDF, RDFS, OWL, and SPARQL provide building blocks towards that goal and have favoured the development of ontologies to describe various aspects of the research domain.

However, the development of ontologies for the funding aspects of research and their relations to research activities, actors is still quite in its early stages. In particular, while few ontologies exist (see section 2), they mostly envisage only some of the important semantic elements (typically those relative to projects and grants), as we will show.

This note presents a novel ontology, developed to manage data on research grants and projects, but also notably to conceptualise funding policies and instruments, facilitating the integration and interoperability of such information with other data and from various sources in the framework of the so-called Linked Data. The ontology has been dubbed DINGO (Data INtegration for Grants Ontology). It provides an extensible, interoperable framework for formally modeling the relevant parts of data in this knowledge area.

DINGO particularly facilitates the effort of putting analysis of funding activities and policies in broader context and comparative perspectives, which is much needed when assessing research, policies and their impact. In this way, DINGO will be beneficial in practice at several levels. For instance, by increasing the capacity of analysis to inform policy and strategic discussions, as well as reducing the effort of researchers and officers in giving evidence of policy compliance.

Indeed, one specific characteristic of the knowledge area DINGO aims to describe is its variety. The existing funding activities and policies show a large spectrum of practices, with remarkable diversity and complex semantics. This constitutes a serious difficulty when trying to put funding activities and policies in context and comparative perspectives. DINGO has therefore been specially designed to cope with this, by a rigorous conceptualisation of commonalities via a number of ontology classes and properties, together with other classes that allow tuning semantic specializations to the specific cases when modelling data.

This also allows DINGO not only to be effectively used as a pure domain ontology specific to research activities, but in fact to perfectly model even other domains where funding activities play a relevant roles (such as the arts, cultural conservation, and many others). DINGO has therefore, in some respects, also the multi-domain usability typical of more upper ontologies (we use here the classification ad definitions of ontologies by Guarino [16]).

DINGO is fully documented at *https://w3id.org/dingo*, and a machine readable version of the ontology is available at *https://w3id.org/dingo* in RDF-Turtle by redirection when visiting with the "text/turtle" header (it is also available at *https://dcodings.github.io/DINGO/DINGO-OWL.ttl*).

This article is organised as follows. Section 2 discusses related work. Sections 3, 4, 5, 6 and subsections thereof present the aims, development guidelines, community uptake, maintenance and evolution, and main features of DINGO (we leave the detailed description of the ontology to its documentation, available online). We conclude in section 7, where we also comment on future potential directions of development.

2 Related Work

A few works exist modelling data related to funding and research, although to our knowledge none has been dealing with the aspects pertaining to research (funding) policies together with the rest.

One of the earliest efforts to create a data model for the management of research funding data is CERIF (Common European Research Information Format), [22]. It is an extremely rich and detailed vocabulary for research management, with a considerable number of entities and relations, and a high granularity. However, it does not conceptualise aspects related to policies.

CERIF, conceived for CRIS (Current Research Information Systems), has deep roots in relational database modeling more than in the semantic/knowledge graph one, as visible from some of its characteristics. For example, one of its main features is the presence of "link entities" such as project-organisation, project-person, and so on. They are in fact relationships rooted in relational database reification practices (which differ from what reification is in the framework of knowledge graphs and semantic web). Such "link entities" have however less straightforward interpretation in terms of semantic concepts (they often represent couples of concepts), which would affect inferences. We will show how DINGO avoids this problem and yet manages to capture the aspects of interest.

Related to CERIF is the OpenAire data model [24]. *OpenAire* [23] is an infrastructure that links research outcomes to their creators, enabling discoverability, transparency, reproducibility and quality-assurance. The OpenAire data model uses part of the CERIF vocabulary (including some of the "link entities") and combines them with the OpenAire guidelines.

A few OWL-based ontologies exist describing funding in research. Compared to CERIF, they are fully framed in semantic modeling. The most well-known ones (and in fact the only ones to our knowledge) are FRAPO (Funding, Research Administration and Projects Ontology) [14], [29], and the Springer Nature SciGraph Ontology [34].

These are actually part of larger ontologies or ontology collections mainly aiming at categorizing scholarly data, such as publications and other similar outputs, rather than focusing exclusively on the funding and research landscape. They are thus tuned for those other purposes and have specific limitations. For example, the SciGraph one does not appear to distinguish the concept of "grant" as funding from the concept of "research project" and thus would not allow to easily model for many existing funding practices and uses cases (for instance, the case of projects with multiple grants, either co-occurring or in sequence). FRAPO instead lacks classes and properties for relevant concepts such as "principal investigators" and others . Moreover, neither ontology conceptualises the domain of funding policies.

In addition to these, there is a growing number of initiatives addressing other dimensions of research data than the funding-project ones. To cite a few: *OpenCitations* [30], which is dedicated to open scholarship and open bibliographic and citation data; *SMS* (Semantically Mapping Science) [3], a platform integrating heterogeneous datasets for science, technology, innovation studies; *VIVO* [9] an open source software and ontology for representing scholarship and scholarly activity. Finally one can mention also *CASRAI* (Consortia Advancing Standards in Research Administration Information) [7], which does not provide an ontology, but a glossary of research administration information.

We will discuss the part of schema.org [33] dealing with funding data in Section 3, as it was in fact inspired by DINGO.

We finally would like to mention the FP Ontologies [26]. They do not deal with research funding, but model some aspects of projects. Web-searching them points to the webpage at [26], but in fact we could not find documentation nor download any serialisation from that page.

3 Community Uptake and Use of DINGO

DINGO has been first presented to the public in the late 2018, and has led to a number of uses, both directly for data modeling and knowledge bases creation, and as a basis or inspiration for related ontology modeling efforts.

The first public presentation of DINGO has occurred at the workshop "Wikidata for research", Berlin, 17-18 June 2018, where feedback and input were exchanged with a working group of participants, which lead to the linking of DINGO with the Wikidata graph.

DINGO also inspired the part of the schema.org model specific for grants and funding (as mentioned explicitly at the issue 343 of the schema.org release of 2019-04-01[3]. Schema.org 's model covers however only a subset of DINGO's .

Furthermore, DINGO has been adopted to model the knowledge base of the European Commission data hosted and available now in the OpenAire LOD service (at *http://lod.openaire.eu/eu-open-research-data*), and as one of the basis of the schema for the GRANTID initiative of CrossRef [10] (one of the authors of this article, D.C., has been a member of the technical group for the schema[4]).

4 Ontology Mapping, Reuse and Extensions in DINGO

Ontology mapping is a key challenge of the Sematic Web and of Linked (Open) Data for several reasons. Ontology reuse is also a good knowledge engineering practice, increasing the interoperability of systems.

In the framework of semantic modeling and the Semantic Web, reuse and mapping are particularly complex. On the one hand, the de-centralised nature of the web favours the development of several ontologies and data models, which often overlap partially. On the other hand, the single ontologies are generally created with specific goals, and thus even when they are developed to model data from the same domain(s), they will generally present subtle semantic differences even in seemingly general concepts.

In the case of research data, mapping and reuse are further complicated by the multiplicity of actors and the diversity of types of funding practices, policies and data. But on the other hand, this same issue prompts to maximise the semantic modeling power of an ontology by linking it with overlapping ones in order to achieve maximum interoperability.

DINGO was therefore built from the start with a particular attention to ontology mapping. Pure reuse has been possible only to a certain extent, because ontologies covering overlapping knowledge areas (such as those mentioned in Section 2) do indeed present subtle but relevant semantic specificities.

The mapping in DINGO makes use of the SKOS ontology/data model mapping properties (documented at [1]) and RDF and OWL class and properties axioms such as owl:equivalentClass and owl:equivalentProperty when applicable. In fact, the establishment of mapping using the latter owl axioms is generally quite complicated, as they require establishing that the full extension of the relative classes/properties are equal. This is typically a difficult task in the case of a complex knowledge area such as the one of research, and has therefore being done carefully and rather conservatively in DINGO.

DINGO is presently mapped to the Wikidata data model, to schema.org and to the FRAPO ontology. There is also interest in linking DINGO with the vocabulary provided by CERIF, and future developments have been already planned in that sense.

[3] Visible at *https://schema.org/docs/releases.html*).

[4] See *https://www.crossref.org/working-groups/funders/*).

Besides that, DINGO also reuses several other ontologies, such as SKOS, schema.org and DublinCore [11], and is inspired by the FAIR principles [39] for data publication.

Finally, DINGO has been designed to be easily extensible to adapt to the various possible use cases and diversity of data and existing practices. The ontology presents "hook properties" (such as *product_or_material_produced*) that allow to extend DINGO linking, for instance, to data modeled with the many ontologies dealing with scholarly and publishing data (such as the SPAR ontologies [29], the Semantic Web Journal (SWJ) ontology [20], the Semantic Web Conference (SWC) ontology [37], the Semantically Annotated LaTeX (SALT) ontologies [15], the Nature Ontologies [18], the SciGraph Ontologies [19], the Conference Ontology [25], BIBFRAME [4] and bibkliotek-o [5]).

5 The DINGO Ontology

5.1 Aim of the Ontology

The principal aim of the DINGO ontology is to provide a machine readable extensible framework to model data relative to projects, funding, policies and actors. The original intended users for such frameworks were the stakeholders in the research landscape with their very different use cases.

As discussed in Section 1, semantical modeling of that knowledge area faces, among others, one main difficulty: there exist a huge variety of funding, policies, practices and research activities. Due to the aim of being able to cope with this, as we illustrate also in Section 5.3, DINGO is finally applicable also to domains different than the one of pure research where the funding aspects are relevant, for example in the arts, cultural conservation and the like.

DINGO's development was also driven by the goal of being rich enough to

1. integrate and accommodate existing systems and data instances
2. satisfy complex as well as simple use cases, also by straightforward extension.

This set of principal design goals and requirements also allowed to work toward the realisation of additional (and important) objectives, such as promoting the opening up of funding data, and the linking and re-using of data.

Special care has been devoted to minimizing the efforts in applying/adopting the model by users. In particular, while the model has been created using Linked Data fundamentals, it is apt to different implementations and integration in non-graph-type data bases, hence it does not address specifically the optimization of graph inference and graph-based queries.

5.2 Approach to Ontology Design

Ontology generation is a complex process that has been scrutinised in the literature and has led to the establishment of a number of engineering best practices, see for example [13], [38], [32], [16], [17], [31]. The design of DINGO has followed such best practices. The main guidelines followed have been:

- a mixture of middle-out and bottom-up approach: starting from actual data (such as funding data from various agencies, see below), several main concepts have been designed and the ontology generation has proceeded by distinguishing a number of commonalities (generalisations) and specificities; the advise of domain experts has also been essential, mostly profiting from the fact that DINGO has been developed at the ERC(EA) [12]
- practical usability of the end results
- interoperability/integration from the inception with other graphs (for instance, Wikidata and Schema.org)
- sufficient granularity to allow for efficient monitoring and evaluation purposes, but also sufficient generality to accommodate potentially all funding data, thus providing the whole benefit of a large Linked Data Graph. DINGO is straightforwardly extensible to provide additional granularity
- coverage of all areas of interest, also for non-academic actors and stakeholders.

For DINGO's data-based mixed middle-out and bottom-up development we have used various research funding data, in particular looking at data freely provided by several funding agencies. For instance, we have used data from the European Union Funding (Research Framework Programmes), The Australian Research Council (ARC), the Swiss National Science Foundation (SNSF), the Croatian Science Foundation, the US National institute of Health (NIH), the US National Science Foundation (NSF), the various UK agencies coordinated by the Research Councils UK (RCUK).

Finally, we have adopted elements of agile development, not dissimilarly from what proposed in [28], for instance concerning unit testing.

The tools employed in the design and coding process of DINGO have been: UMLet [2] with some custom diagrams elements for graphical representations, while the documentation has been build using a custom software written in Python (unpublished) to automatically generate human-readable HTML documentation from OWL ontologies serialisations (see section 5.4).

5.3 Ontology Description

Here we describe DINGO's main components and their features, while the ontology full specification is available at *https://w3id.org/dingo*.

DINGO is an OWL-DL ontology comprising 40 classes and 68 properties. Its classes provide an articulated conceptualisation of entities relevant for the characterisation of data in the research, funding and research-related domain. In particular, besides classes for Projects, Grants, FundingAgency and others, there are specific classes for describing funding policies, with several specific subclasses (which can straightforwardly be expanded).

As we said, the variety and diversity of funding realities (which we will also call "realisations") makes semantic conceptualisation particularly difficult. For example, different funding agencies/funders classify their funding policies in various and discording ways, sometimes using the same word for different things (for instance, the terms funding scheme/programme/action). Also the role and characterisation of the different actors in projects and grant agreements are quite diverse. Such modeling complexity appears not only at the level of concepts, but also of relations/properties. Notably, the relationships between the funding and the research enterprise can be various and rather complex.

Furthermore, alongside concepts definition, additional complexity is given by the variety of use cases: besides the simple case of one grant funding one project, often multiple fundings are attached to a single project (either in sequence or at the same time), or a single grant funds several (sub)projects.

Therefore, DINGO's properties and classes have been designed to allow high modeling capability to represent such variety of concepts and realisations.

DINGO's main features are as follows:

- it defines a number of principal classes: **Project**, **Grant**, **Funding Agency**, **FundingScheme**, **Role**, **Person**, **Organisation**, **Criterion**, various sub-classes of those and some related specialised classes;
- a **Project** is an organised endeavour (collective or individual) planned to reach a particular aim or achieve a result
- a **Grant** is a disbursed fund paid to a recipient or **beneficiary** and the process for it; DINGO focuses on the main definition of "funding" (which is defined as "money for a particular purpose; the act of providing money for such a purpose" both in the Cambridge, Oxford and Collins dictionaries [8], [6], [27]), but can be extended to other types of funding (non-monetary ones), see Section 6.
- a **Project** may be funded by one or more Grants simultaneously or in sequence
- a **Grant** may fund one or several Projects
- **Grants** can be awarded to Person(s) and/or to Organisation(s)
- **Projects** can be participated by **Person**(s) or by **Organisation**(s), hence a **participant**, characterised by a **Role**, can be a **Person** or an **Organisation**
- the **Role** class can be used to specify the semantics of the participation to a Project or role in a Grant. This class provides instruments to model a large variety of semantic types, to account for the variety of practices found in actual data
- types of organisations can be specified using one of the several sub-classes of **Organisation** or creating new ones
- a **participant** (**Person** or **Organisation**) in a **Project** may not actually be **beneficiary** of a specific **Grant** funding the Project; accordingly, DINGO reflects that particular participants of Project and beneficiaries of Grant funding the same Project may be different
- temporal aspects of the various concepts can be fully modeled, and are expressed by specific properties (*start_time*, *end_time*, *inception*, and so on)
- **Funding Agencies** are the organisations materially disbursing and administering the Grant process
- **Funding Schemes** are funding instruments accompanied by specifications of Grant coverage, eligibility, reimbursement rates, specific criteria for funding, grant population targets, and similar features. Such specifications constitute one or more **Criterion** to award funds (Grants);

– **Funding Schemes** may be sub-specifications of other Funding schemes; this recursive relation allows to model existing complicated hierarchies of funding instruments. The word "Scheme" has different meanings for different funding agencies/funders. In fact, there exist other related terms such as funding program and funding action, in particular in case of a hierarchy of funding instruments. DINGO represents the generalisation of such instruments via the class FundingScheme, and expresses the taxonomy and relations among the various instruments via the Criterion class and subclasses and the FundingScheme (recursive) class properties
– **Criteria** can be of different nature, modeled in DINGO via different subclasses; multiple criteria can coexist in a single funding scheme; they provide a conceptualisation (straightforwardly extensible by sub-classing) to characterise funding policies in relation to funding schemes and activities.

We present in Figure 1 a graphical illustration of the main parts of the ontology, both classes and properties, portrayed respectively by ovals and arrows.

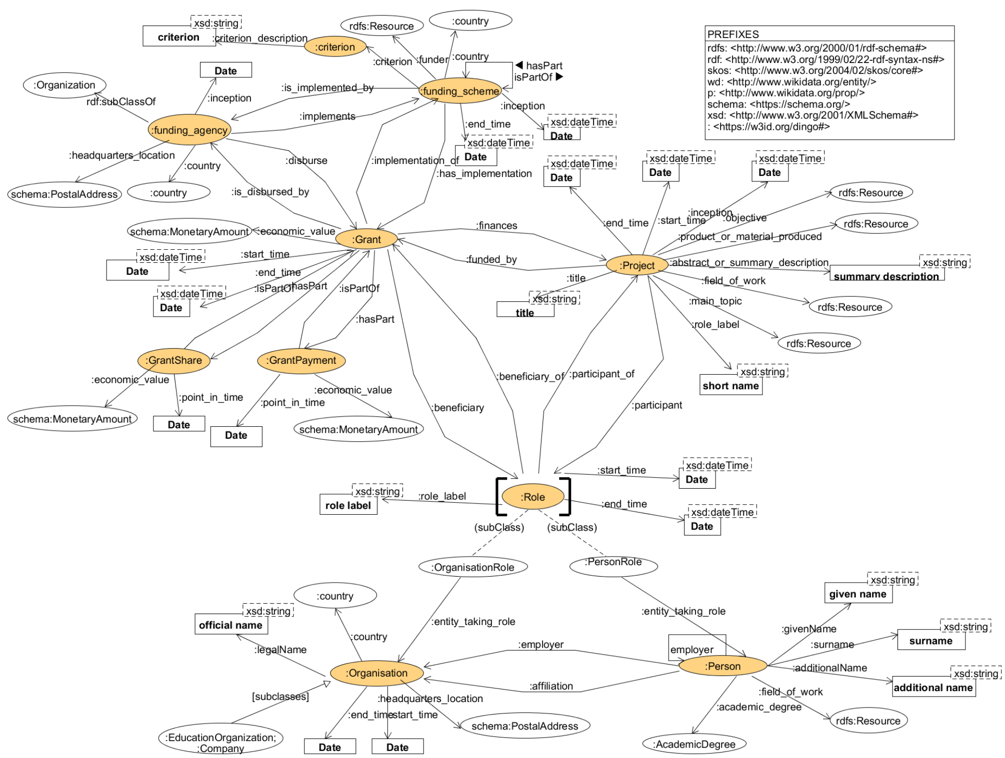

Fig. 1. Graphical representation of DINGO (main parts).

5.4 DINGO Documentation and Machine-readable Serialisations

DINGO is documented at https://w3id.org/dingo. The documentation has been created using custom software written in Python (unpublished) that automatically extracts classes, properties, individuals, annotations, axioms and namespaces from OWL ontologies and produces human-readable HTML.

The machine-readable serialisation of DINGO is provided in RDF-Turtle language, and available at *https://w3id.org/dingo* by redirection when visited with the "text/turtle" header. We also provide, at the same address, a Shape Expression [35] data model for validation of data triples.

6 Maintenance and Evolution of DINGO

DINGO's maintenance is continuous and evolutive in nature, because DINGO aims at effectively modeling funding and research practices, which continuously evolve by themselves. As mentioned, the evolution and extension of DINGO will be eased by the specific design choices made in creating it, which provide for a high modeling power to cope with the variety of existing funding realities. Hence, in many cases the required evolution/extension will be minimal (just by subclassing for new concepts).

DINGO can however be straightforwardly extended even in more orthogonal directions. For example, as discussed in Section 5.3, DINGO focuses on the main definition of "funding" (the monetary one, see the Cambridge, Oxford and Collins dictionaries [8], [6], [27]), but it can be extended to non-monetary funding simply by providing parallel classes as Grant, with properties for the specific resources provisions (and possibly a generalisation class to describe their commonalities).

7 Summary and Outlook

We have presented an OWL-based ontology for research and funding called DINGO and illustrated its main features, uptake and evolutive maintenance.

DINGO has the potential to constitute a key ingredient for a set of orthogonal and interoperable ontologies for the knowledge area of funding, research and their impact. In particular, there is a lack of ontological conceptualisations concerning the domain of impact and impact studies, hence, for instance, we have already planned the development of ontologies for data relative to impact indicators.

Moreover, as we mentioned, DINGO has features that enable it to be both used for domain knowledge graphs specific to research, as well as in graphs for other domains where funding aspects and policies are of interest (such as the arts, cultural conservation, and the like).

DINGO has already been used in a number of projects, as described in Section 3. We plan to engage further with relevant communities to create systems that offer information on research funding in distributed manner using DINGO. This should eventually lead to a truly global Open Research Information Graph providing access to data in several interconnected research information systems.

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