MAEO: An Ontology for Modeling Agents, Experts and Expertise within an Open Online Materials Modeling MarketPlace

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Abstract

This work describes the MAEO ontology, which models agents, experts, expertise and knowledge providers in general within the context of an online, open marketplace for materials modeling and related collaboration activities. Such a marketplace is meant as a one-stop shop for enabling and accelerating materials modeling in industry, and is currently under development within the Horizon 2020 "MarketPlace" project. The MAEO ontology has been developed as the underlying basis for the online platform provided by the project, where users may look for experts with a certain expertise, and the latter may subscribe and be made visible and searchable by the users. As it stands, the MAEO ontology is part of a larger effort of ontological modeling for the Materials Modeling area having the EMMO (European Materials Modeling Ontology) as its root, and as such can be seen as an EMMO-based, application-level ontology. This work thus details the ontology's domain, purpose and structure, and underlines the connection with external ontologies, while also providing a brief description of its usage and technical implementation.

Keywords

ontology, materials modeling, marketplaces, experts, expertise, agents, knowledge providers

1. Introduction, Domain and Purpose of the Ontology

Since its inception in 2014, the European Materials Modeling Council (EMMC) [1] has been carrying out a number of initiatives meant to improve the interaction and collaboration between all of the stakeholders involved in different types of modeling and digitalization of materials, to increase the adoption of materials modeling in industry and to bridge gaps between academic and industrial players within this context. In this regard, one such initiative has the purpose of bringing about a unified, open, online "marketplace" for materials modeling and related collaboration activities. Such a marketplace, meant as a one-stop shop for enabling and accelerating materials modeling in industry, is currently under development within the context of the Horizon 2020 "MarketPlace" project [2], and is expected to be a virtual place where experts in materials modeling and related activities can register and be found by interested users. The

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MarketPlace Agent and Expert Ontology (MAEO) has been designed and implemented as the underlying data structure of the web application representing this online marketplace, and as such it is meant to model agents and experts, and in general knowledge providers, with their corresponding details and expertise. At the same time, even though mainly serving a very specific purpose, MAEO has also been designed as part of the larger ontological effort of the European Materials Modeling Ontology (EMMO) [3] with which it provides a high-level alignment, and is thus considered as an application-level ontology of EMMO's ontological layers.

2. Structure of the Ontology

This section describes the MAEO ontology in terms of its class hierarchy, with each class listing its own subclasses and properties (if any). Class names are in bold, whereas object properties are in bold and italic and are followed by the class name representing their range (the object of the relationship) enclosed within plain brackets, and datatype properties are in italic. A depiction of MAEO's class hierarchy is provided in Figure 1.

- **MarketPlaceAgentOntology**: this is the root class of the MAEO ontology, introduced for providing the ontology itself with a tree-like structure, with all of its other explicitly defined internal classes being subclasses of this class at various hierarchical levels.
- **MarketPlaceAgent**: it models a generic Agent in the MarketPlace, i.e. an entity that can act on the MarketPlace. It has two major subclasses:
  - **User**: it has been introduced in order to model a generic user of the MarketPlace application.
  - **KnowledgeProvider**: it models a generic provider of knowledge that possesses a certain expertise. It is thus the domain of the ***hasExpertise*** (Expertise) object property, and it includes the following subclasses:
    * **Expert**: a knowledge-providing human expert that possesses a certain expertise and whose information can be stored and accessed within the MarketPlace application. It sports datatype properties like *experienceInYears* and *yearsOnMarketPlace*, and it is the domain of several object properties: ***worksAt*** (ExpertOrganization), ***requests*** (DailyRate), ***hasCertification*** (Certification), ***hasExternalProfile*** (ExternalProfile), ***isUnderContract*** (Contract).
    * **Organization**: a knowledge-providing juridical entity that possesses a certain expertise, and may or may not have something to do with Experts (see the "Expert Organization" class below).
    * **Team**: a knowledge-providing group of people.
    * **Lab**: a knowledge-providing laboratory.
- **ExpertSubjectiveProperty**: it is meant to represent the superclass of subjective properties that may be possessed by entities modeled in the MAEO ontology. At the moment, it includes a single subclass:

– **Expertise**: it represents the expertise possessed by a generic knowledge provider, by which users of the MarketPlace application can look for experts and such (and vice versa).

- **ExpertObjectiveProperty**: it is meant to represent the superclass of all of the objective properties potentially possessed by the entities of the MAEO ontology. At the moment, it includes a number of high-level subclasses modeling categories of objective properties related to experts and organizations, as follows:

  – **PersonalDetail**: it models the personal details (name, address, contacts, etc.) of a human expert. It includes a two subclasses:

    * **Profile**: includes the details of a human expert's profile, expressed via the datatype properties: *profileUsername*, *profileEmail*, *profileName* and *profileAddress*.

    * **ExternalProfile**: represents a connection with an external profile for a given experts, e.g. a social network profile on LinkedIn, Facebook, etc. It sports two datatype properties, *i.e. externalProfileUrl* and *externalProfileName*.

  – **ProfessionalDetail**: it is meant to encompass the professional details of a human expert, e.g. title, role, qualifications, languages spoken, current or desired daily rate for hiring and its corresponding remuneration, etc. It has three subclasses so far:

    * **DailyRate**: it models the daily rate a human experts requests. It is the domain of the object property **amountsTo** (Remuneration).

    * **Remuneration**: it models the remuneration value and currency of the daily rate requested by a human expert, as well as the one associated with an existing contract a human expert may be under. It includes self-explicative datatype properties like *remunerationValue* and *remunerationCurrency*.

    * **Language**: it describes a language known by a human expert. It includes datatype properties like *languageCode* and *languageName*. By reification (via the rdf:Statement construct), the datatype properties *languageType* and *languageLevel* are associated with a "Expert knowsLanguage Language" triple.

  – **ContractualDetail**: it describes the details about the contract a human experts is currently under. It has one subclass at the moment:

    * **Contract**: it is meant to model the actual contract(s) a given expert may be currently under. It includes datatype properties like *contractType* and *contractConstraint*, the latter modeling potential legal or business constraints and limitations a contract may specify with regard to potential consulting and collaboration activities an expert may be allowed to carry out. It is the domain of the object property **hasRemuneration** (Remuneration).

  – **CertificationDetail**: it is meant to describe the details of certifications possessed by a human expert. It has three subclasses:

    * **Certification**: it describes an actual certification a human expert may possess, with datatype properties like *certificationTitle* and *expirationDate*. It is the domain of the object property **issuedBy** (CertificationAuthority).

* **CertificationAuthority**: it models the authority that has issued a certification. It has the datatype property *certificationAuthorityName*.
- **OrganizationalDetail**: it is meant to model the details of the company, institution, organization an expert may be working at/with. It has two subclasses at the moment:
    * **Location**: it describes the physical address of an organization. It is the range of the object property (ExpertOrganization) *isLocatedAt*, and it has the datatype property *address* (additional datatype properties are still under evaluation).
    * **ExpertOrganization**: it models the organization an expert may be working at/with, distinguishing it from a knowledge-providing organization. As such, it is the range of the object property (Expert) *worksAt*. An instance of the former may also be the same organization as an instance of the latter; in order to model such a case, the object property *refersToOrganizationWithExpertise* (domain: ExpertOrganization, range: Organization) has been introduced for connecting the two.

All of MAEO's object properties have been defined as subproperties of a "container" object property, namely ***MAEOObjectProperty***, as stated in Section 3 when discussing EMMO's connections with MAEO.
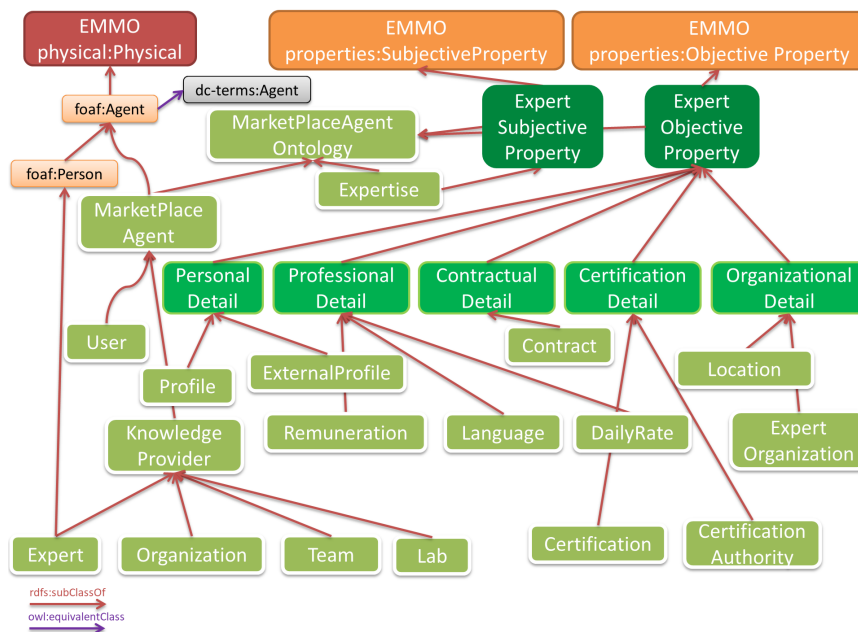

Figure 1: MAEO's class hierarchy, where the green entities (with three different shades of the color), whose namespace is not shown for brevity, are the "proper" classes defined in MAEO, whereas the differently-colored entities belong to the external ontologies MAEO has been connected with.
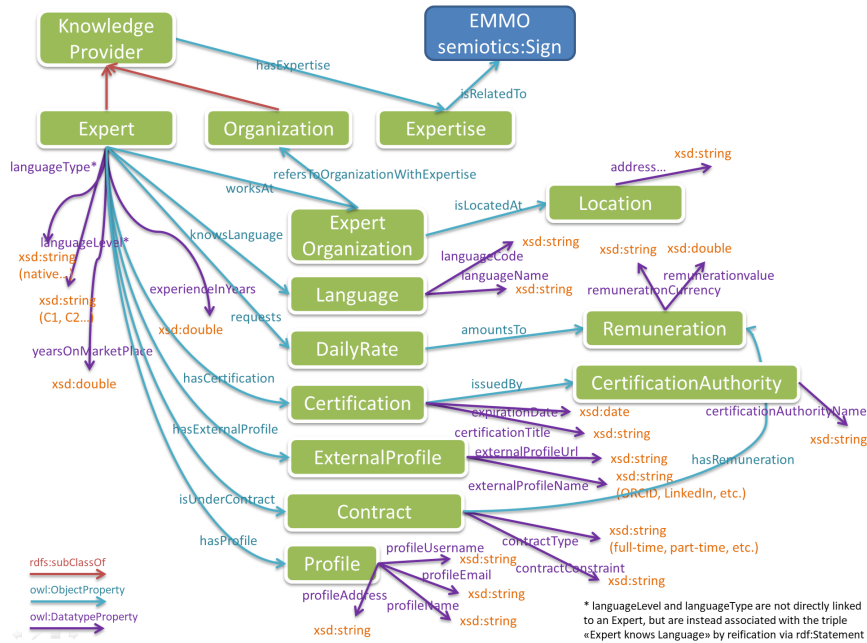
Figure 2: A partial view of MAEO, showing the OWL ObjectProperties and OWL DatatypeProperties defined in the ontology among its major classes. Most of the ontological design, as apparent from the picture, revolves around the "Expert" concept.

3. External Ontologies Involved

The external ontologies used within MAEO are the following: (i) The Friend-Of-A-Friend (FOAF) ontology [4], and (ii) The European Materials Modeling Ontology (EMMO) [3]. These ontologies are aligned with a number of MAEO entities via relationships within the class and property hierarchy and via specific properties. Specifically:

- A MarketPlaceAgent, which is one of MAEO's core schema concepts, is defined as a subclass of `foaf:Agent`, which in turn is defined as a subclass of EMMO's Physical. This means that all of the instances of MarketPlaceAgent will be instances of foaf:Agent as well as instances of EMMO's Physical.
- An Expert, which is a more specific class along the hierarchy starting from MarketPlaceAgent, is also defined as a subclass of `foaf:Person`, which in turn is a subclass of `foaf:Agent`. Thus, all instances of Expert, aside from being instances of MarketPlaceAgent (among the others), will be instances of `foaf:Person` as well.
- ExpertSubjectiveProperty and ExpertObjectiveProperty are defined as subclass of EMMO's SubjectiveProperty and EMMO's ObjectiveProperty, respectively. Thus, every instance of ExpertSubjectiveProperty will be also instance of EMMO's SubjectiveProperty, and every instance of ExpertObjectiveProperty will be also instance of EMMO's ObjectiveProperty.
- The Expertise concept has been connected via a "isRelatedTo" relationship with EMMO's Sign concept. The exploitation of this connection is still under discussion and subject to extensions and refinements.

- Every object property defined in MAEO is a subproperty of MAEOObjectProperty, which in turn has been declared as a subproperty of EMMO's hasProperty.

It is important to underline that, for development purposes, the involved EMMO concepts aligned with MAEO have been included after mapping their hexadecimal URIs to a more developer-friendly verbose version. For the sake of distribution, it is of course required to map them back to their original form, which can be programmatically done via an automatic procedure.

4. Technical Details and Availability

The MAEO ontology has been defined by using the RDF [5], RDFS [6] and OWL [7] formalisms, and has been deployed and tested on a Stardog triplestore [8]. Support tools for development and testing have been developed in the Java language, version 1.8+. The OWL axiomatization of the ontology is available at the following URL: https://gitlab.cc-asp.fraunhofer.de/ontology/applications/marketplace/experts-ontology.git.

5. Usage, Evaluation and Concluding Remarks

The MAEO ontology is expected to be used as both a modeling and practical support to the MarketPlace platform, including functionalities like the acquisition and storage of information related to experts and expertise, and their search by a number of parameters. In this regard, The MAEO ontology is undergoing a pragmatical evaluation process that is meant to provide it with an "operational" definition of correctness, in terms of its effectiveness in capturing, storing and making available the information needed by the MarketPlace platform for its expected functionalities. Given that the platform itself is still a work in progress, a number of refinements and extensions are expected to occur within the MAEO ontology as well throughout the life-cycle of the MarketPlace project. Besides, EMMO itself is moving towards a stable 1.0.0 release, and even though MAEO's alignment with it relies on rather stable elements and properties, minor adjustments may still be needed in the coming months.

Acknowledgments

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