Ontology-quality Evaluation Methodology for Enhancing Semantic Searches and Recommendations: A Case Study

Paula Peña[1][a], Raquel Trillo-Lado[2][b], Rafael del Hoyo[1][c],
María del Carmen Rodríguez-Hernández[1][d] and David Abadía[1][e]
[1]*Technological Institute of Aragon (ITAINNOVA), María de Luna 7, Zaragoza, Spain*
[2]*University of Zaragoza, Zaragoza, Spain*

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Abstract: In the big data era, there exist an increasing demand of models and tools to evaluate quality of data used in decision-making and search processes, as decision based on wrong and poor data quality can lead to enormous loss. Thus, data has become an asset and the most powerful *enabler* of any organization. In this context, ontologies and semantic techniques have gained importance in order to represent data sources and metadata during the last decades. In this paper, we describe our work-in-progress concerning to the generation of models that encourage data quality through the use of ontologies. In particular, we present a use case where an enriched ontological model of ESCO (European Skills, Competences, Qualifications and Occupations) is used to improve the effectiveness of a search and recommendation system. In more detail, we focus on how ESCO is enriched by following METHONTOLOGY methodology and 101 methodological guidelines. We also provide the design of a search and recommendation system oriented to labour market that exploits the enhanced ontology to suggest qualifications required by job seekers and employees to reach a specific occupation position and different training itineraries to get those recommended qualifications.

1 INTRODUCTION

The progressive emergence of numerous and significant technological changes in the Information Technology (IT) industry has been the driver for the large amount of data generated and accumulated at an unprecedented speed. Data has become the main asset and the most powerful *enabler* for any type of organization or institution to make operational, tactical and strategic decisions. For this reason, data quality is seen as a key element, not only to be able to generate value, knowledge and competitive advantage, but also to prevent adverse consequences from being incurred by decisions based on wrong data or with inadequate levels of quality.

In recent years, research works have been carried out with a great diversity of approaches on the issue of data quality (Cai and Zhu, 2015; Taleb et al., 2018). Due to the evolution of the big data and its new characteristics, in the state-of-the-art, there is a lack of data-quality methods to reach optimal solutions that consider the continuously growing data volume with a reasonable time and cost. In addition, there are no mature models to assess data quality to support decision-making and address problems at the business level.

In the meantime, in a world overflowing with unstructured data, semantic technologies are presented as an effective tool for understanding, storing, relating, sharing, searching and finding information. The use of these technologies are a suitable means for intelligent analysis of big data based on artificial intelligence (AI) techniques and value generation. Exploring the connection between data quality and semantic technologies in this era of big data and data-driven decision making is a broad field of research.

In this context, we describe our work-in-progress concerning the generation of models that foster data quality through the use of ontologies. These models can be used for the intelligent analysis and data management, and value extraction and decision making with large volumes of data from diverse sources and with a variety of uses of those data in business and

[a] https://orcid.org/0000-0001-5750-6238
[b] https://orcid.org/0000-0001-6008-1138
[c] https://orcid.org/0000-0003-2755-5500
[d] https://orcid.org/0000-0002-0062-9525
[e] https://orcid.org/0000-0002-6005-3863

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institutional contexts. In particular, we focus on how improving the data model that describes the information used by a search and recommendation system oriented to labour market and enhances the performance of the system.

We propose to introduce an enhanced ESCO ontology[1] in a dynamic information retrieval system oriented to labour market: different training itineraries are suggested to job seekers and employees who want to reach a specific occupation position. We postulate that improving the quality of the ontologies used improves the efficiency or performance of the systems. Thus, a proposal for a new approach and metrics to evaluate how the quality of the recommended results depends on the built ontology quality is outlined.

This paper is organized as follows. Section 2 presents related work on ontology engineering and quality evaluation. Section 3 describes the purpose and motivation of our work through a use case and the high-level information retrieval system architecture used. An ontological enhancing methodology is detailed and the quality evaluation approach to work on is outlined in Section 4. Finally, Section 5 presents conclusions and highlights lines of future work.

2 RELATED WORK

Semantic technologies are presented as an important means in unstructured information management processes (understanding, sharing, searching, etc.), but also for intelligent analysis of big data based on AI techniques and value creation. In this context, ontologies play a critical role to provide a shared formal representation of knowledge regarding naming and definition of types, and properties and interrelationships of entities that exist in a particular domain of discourse (Gruber, 1993). In this section, we discuss related work on existing ontology-engineering methodologies and quality assessment of built ontologies.

2.1 Ontology Engineering

Many ontology engineering methodologies (OEM) have been proposed to build ontologies over the last decades, although there is no a standard method or widely used guidelines. The available methodologies have either been initially proposed or emerged from experiences and insights achieved during ontology development for different projects. A critical analysis and comparison of these methodologies is carried out in (Iqbal et al., 2013).

[1] https://ec.europa.eu/esco/portal/home

In this paper, we do not propose another ontology development methodology, but an approach that facilitates the integration and enhancement of existing ontologies in order to improve the performance of systems. We pursue to analyze how the quality of ontologies influence the effectiveness of the system and the achievement of the business goals of an enterprise or institution. Hence, we consider the *METHONTOLOGY* methodology (Fernández-López et al., 1997) and *101 method* guidelines (Noy and McGuinness, 2001) to enhance the ESCO ontology and evaluate how it impacts on the performance of the application system.

The use of ontologies for describing data sources has been exponentially increasing in the last decades, especially in the context of the semantic web. Ontology alignments are required in order to integrate the information from several data sources and manage heterogeneity. Ontology matching consists of finding correspondences between semantically related entities from different ontologies and purposes (Shvaiko and Euzenat, 2013).

Along the time, a wide range of ontology matching techniques, systems and tools have been proposed. Some of the more recent ones are *SAMBO*, *Falcon*, *DSsim*, *RiMOM*, *ASMOV*, *Anchor-Flood* and *AgreementMaker* which have appeared to cover gaps from previous works (Otero-Cerdeira et al., 2015; Bellahsene et al., 2011; Gal and Shvaiko, 2009; Choi et al., 2006; Zimmermann et al., 2006; Bouquet et al., 2005). Besides, while the current research focuses mainly on fully automatic matching tools, the user involvement and collaborative interaction become new challenges for ontology matching (Shvaiko and Euzenat, 2013). In this paper, we pursue to evaluate the quality of the results obtained by existing automatic matching tools and techniques. In addition, we will assess the results of the search and recommendation system that includes the enhanced ontology.

2.2 Ontology Quality Assessment

Although a significant amount of research has been conducted about ontology-building processes, there are no mature models to assess ontology quality. Nowadays, ensuring that ontologies are well designed, structured and contain all essential elements, remains a major concern and a challenging task.

Different approaches, aspects, criteria and tools have emerged with the aim to prove ontology correctness and quality. Regarding scopes, domains and ontologies purposes, attempts based on logical or rule, evolution, metric or feature, application, data-driven, evaluation by humans, the *Gold standard* and task

have been proposed (Mishra and Jain, 2020). As a result, various quality metrics and criteria such as accuracy or correctness, adaptability, clarity, completeness or competency, computational efficiency, conciseness, consistency or coherence and organizational fitness, have been proposed in recent years to cover a larger range of quality attributes (Vrandečić, 2009). Some of which are now widely accepted and implemented in frameworks and tools for ontological evaluation. Examples of these are *OntoClean*, (Guarino and Welty, 2004), *ODEval* (Corcho et al., 2004), *OntoQA*, (Tartir et al., 2005), *OQuaRE* (Duque-Ramos et al., 2013), *OntoQualitas* (Rico et al., 2014) and (Zaveri et al., 2015; Abián et al., 2018).

3 PURPOSE AND MOTIVATION

In this section, we describe a case study that illustrates the motivation of our article, which is in the context of a European research project[2]. In addition, we present a high-level view of the architecture designed to facilitate the retrieval and recommendation of relevant information for the construction sector.

3.1 Case Study: DETECTA

This section describes our ongoing work regarding the development of a new dynamic information retrieval and recommendation system (called DETECTA) for the detection of qualification needs of job seekers and employees in the construction sector. We aim at scenarios where the DETECTA platform suggests different training itineraries to users who want to achieve a specific occupation position, by considering the user's profile, desired occupation and external information sources (see Figure 1).

For example, a job seeker or employee from the construction sector has experience in occupations such as *house builder*, *stonemason* and *kitchen unit installer* (mentioned in her/him resume), and now he/she wants to work in the *carpenter* or *construction painter* occupations, but he/she does not have the required studies (skills and competences) to perform them. Based on the current user scenario (the starting point and the desired point that he/she wants to achieve), the system would be able to suggest a training itinerary to obtain the required certificates.

DETECTA is also interesting for different types of enterprises and entities in order to suggest training itineraries to their employees, by considering their

[2] http://www.e-detecta.eu/web/

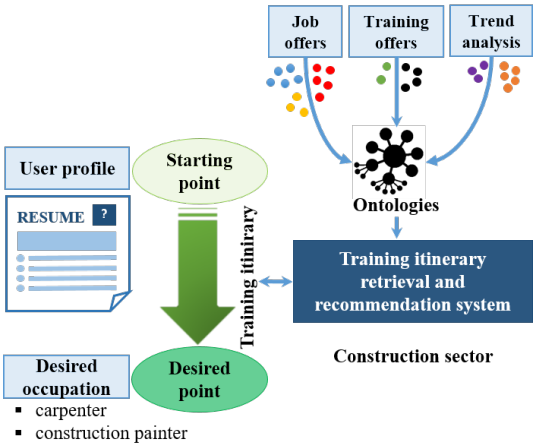

Figure 1: Overview of the user training itinerary retrieval and recommendation process.

target roles, skills and responsibilities along with the business strategic goals.

DETECTA considers a set of data sources related to training and job offers and trend analysis on the construction field (e.g, public European and regional web portals, interviews, newspaper articles, reports, social networks, etc.). Moreover, new data sources can be added dynamically to the system. Initially, we focus on external data sources that provide relevant information (e.g., professional certificates, unregulated certificates, training courses, job offers, etc.) for the countries Spain, France, Ireland and Belgium. In addition, the system exploits existing ontologies. For example, the ESCO ontology (Smedt et al., 2015) that includes concepts such as occupations, skills, qualifications, etc.

3.2 Training Itinerary Retrieval and Recommendation Architecture

The architecture of DETECTA has been designed to facilitate the retrieval and recommendation of training itineraries required by users (job seekers, employees or enterprise manages) in order to achieve their target occupations (see a high-level view in Figure 2). The proposed architecture is composed of the following layers:

- **Data Access Layer.** It provides the access in an abstract way to the information stored in an ontology and the Solr database to feed the DETECTA system. Moreover, in order to model the domain of the search or recommendation system, these data are described and annotated by means of an enhanced version of the ESCO ontology (Smedt et al., 2015). It was enriched with information extracted from external data sources, by using the

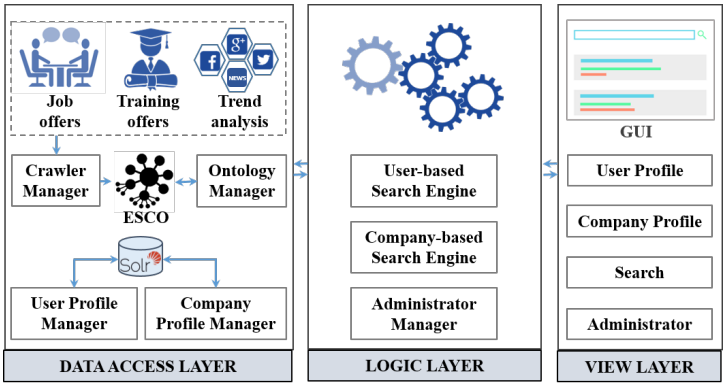

Figure 2: Overview of the training itinerary retrieval system architecture.

Crawler Manager module (see Section 4 for more details). Specifically, we use the *EURES* (EURopean Employment Services) European Job Mobility Portal[3] to extract information about job offers. Regarding training offers, we exploit different web portals (e.g., FUNDAE[4] and SEPE[5] for Spain, Réseau des CARIF OREF for France[6], Dorifor for Belgium[7], and Further Education & Training Course for Ireland[8]) to extract information related to professional certificates, unregulated certificates and training centers. The *Ontology Manager* module is used to access the information stored in the ESCO ontology. Concerning job-trend analysis, relevant and specific context sites are considered in order to detect periodical reports and social networks (e.g. CECE[9]) to be analysed by using Natural Language Processing (NLP) techniques. Finally, the *User Profile Manager* and *Company Profile Manager* modules are responsible for managing (inserting, modifying and removing) the information of the users' profiles, stored in a Solr database.

- **Logic Layer.** It contains the main modules of the DETECTA system, which will be implemented through the software development tool *Moriarty* (Peña et al., 2016). The *User-based Search Engine* module supports a keyword-based information retrieval model. First, the query introduced by the user in the system (through the view layer) is pre-processed, by using different analyzers (e.g., lower filter, stop filter, ASCII filter, etc.). Then, the system retrieves the *K* occupations most similar to the user's query (or desired occupation), by considering occupation alternative labels (e.g., synonyms). For this analysis, the system uses the *Ontology Manager* module (contained in the data access layer) to access the occupations stored in the ESCO ontology. The system seeks the professional and unregulated certificates related to retrieved occupations, discarding those that have been obtained by him/her in the past (contained in the user's profile). Both occupations and certificates are related through common skills and competences. Finally, the system presents to the user a list of certificates required to perform the desired occupation. The user-based search can be multi-target as the user can choose several targets as desired occupation position. In this case, DETECTA suggests a training itinerary with the aggregated information, by enabling to point out incremental training needs in order to achieve the desired occupation. This multi-target suggestion can also apply to the enterprise level by matching common and incremental training needs for the employees, by using the *Company-based Search Engine* module. In addition, the system administration and the programming of crawler web services (e.g., frequency, date and hour of execution of the services, as well as the type of process to apply: synchronous or asynchronous) is also possible thanks to the *Administrator Manager* module.

- **View Layer.** It shows the main components of the graphical user interface (GUI). Through this interface, both the user (job seeker, employee) or company manager can include, modify and remove information in their profile (e.g., personal information, skills, education and working experience). In addition, they can submit queries about desired occupations to perform in the construction sector and receive recommendations about possible training itineraries. The results of the search can

[3] https://ec.europa.eu
[4] https://www.fundae.es
[5] https://sede.sepe.gob.es
[6] https://reseau.intercariforef.org
[7] https://www.fetchcourses.ie
[8] https://www.dorifor.be
[9] https://www.cece.eu/home

be presented to users through a graph or a ranked list. From both alternatives, users can filter certificates by his/her location, as well as navigate over the ontology, which contains information related to the retrieved certificates (e.g., courses, training centers, jobs, occupations, skills, and possible equivalence at European level). Administrators can manage permissions and schedule the execution of maintenance services, such as crawlers to pick job offers and training courses up.

In this paper, we focus on the main components of the *Data Access Layer*. The information contained in external data sources is heterogeneous and changing over time. A deep analysis and pre-processing of the considered data sources is needed to extend the design of the ESCO ontology and automatically populate it with relevant information, used by the DETECTA system. Moreover, the results obtained from the system could be strongly influenced by the quality of the considered and enhanced ontology.

4 ONTOLOGICAL ENRICHMENT AND QUALITY ASSESSMENT

In this section, firstly, we describe the methodology to build the extended version of the ESCO ontology. Then, we present the outlines of a new approach to evaluate how the quality of results obtained from the DETECTA system depends on the quality of the built ontological model.

4.1 The ESCO Ontology

The state-of-the-art on domain ontologies related to jobs, occupation, competences, skills, training and qualifications were analyzed. After that, the ESCO ontology was selected as core of the data model for the DETECTA system. A brief description and the criteria used to adopt it are detailed in the following.

The ESCO (European Skills, Competences, Qualifications and Occupations) ontology model uses relevant concepts and relationships to model the labour market and education and training programmes. It is also enriched with a multilingual European classification of professional occupations, competences and qualifications, which is available in 27 languages and provides descriptions of 2.942 different occupations and 13.485 skills. As new emerging occupations and skills are regularly requested by employers and changes in curricula and in terminology, it is under continuous improvement. The most recent version of ESCO Classification v1.0.5 was published in May 2020. Other popular domain ontologies and models such as HRM (Gómez-Pérez et al., 2007), International Standard Classification of Occupations (ISCO)[10], EQF[11], Fields of Education and Training (FoET)[12] and Statistical Classification of Economic Activities in the European Community (NACE)[13], etc. were considered. Nevertheless, ESCO was selected because most of these ontologies and models were integrated in it and ESCO is a current active project.

4.2 Enrichment Proposed Methodology

For the purpose of this work, in the process of enriching the ESCO ontological model, the methodological guidelines contained in METHONTOLOGY and 101 method have been followed. From a closer insight, these OEMs (Iqbal et al., 2013) recommend a life cycle as well as keeping the reusability perspective in mind to improve standardization and data quality. These methodologies follow an evolving prototype model, their natures are application independent and provide at least some details about the used techniques and activities.

The enhanced ontology has been created using this iterative and incremental development process, which emphasizes the construction of a robust conceptual model, and the clear and concise determination of requirements of the ontology to be built. Phases and activities were defined as shown below:

- *Planning:* establishment of the activities required to obtain the expected result.
- *Specification:* definition of the domain, scope and granularity of the ontology to be improved with the semantics of new resources. Requirements determination for enhancing the ontology.
- *Conceptualization:* definition of a conceptual model, which describes the problem and its solution in terms of the vocabulary of the domain identified in the specification.
- *Formalization:* transformation of the conceptual model into a formal model.
- *Implementation:* codification of the ontology in a formal language such as RDF or OWL. Protégé ontology editor has been used.
- *Evaluation:* verification and validation of the extended ontology through tests that allow its subsequent update, refinement or correction of errors.

[10] http://www.ilo.org/public/english
[11] https://europa.eu/europass/en
[12] http://uis.unesco.org/en
[13] https://ec.europa.eu/eurostat

- *Dissemination:* dissemination of work done and the process to be followed to adapt the new ontology.

The ontology with a set of individuals constitutes a knowledge model. As a key-element of ontologies, classes describe concepts in a domain. Our ontology is constructed based on standard RDF model 1.2 *ESCO ontology*, *FOAF vocabulary*, *vCard Ontology*, *The Organization Ontology* and *OWL Time Ontology*. The main classes are shown in Figure 3 and described as follows:

- *Person:* information on a basic user.
- *JobProfile:* information about the users' job profiles (personal skills, education and certificates obtained and previous work occupation).
- *Certificate:* information related to "Professional" and "Non-Regulated" certificates.
- *TrainingCenter:* information on the companies that give the courses required to obtain a certificate (either professional or non-regulated). It is an *Organization* subclass.
- *TrainingModule:* information on the modules contained in a course.
- *CompetenceUnit:* information about the competence units of a training module.
- *Job:* information on job offers. In this case for the countries of Spain, France, Belgium and Ireland.
- *Employer:* information about companies offering job offers. It is an *Organization* subclass.
- *Sector:* classification of the different sectors associated with the companies that offer work.

To model the DETECTA domain, the ontology uses other main ESCO classes such as *Occupation*, *Skill*, *Qualification*, *Organization* and *AwardingBody* (*Organization* subclass). Basic relationships are defined in the ontology. Each user is related to a job profile. Each certificate is associated with a qualification level, a professional family, a professional area, and a type of modality (professional, not-regulated), as well as one or more occupations, training centers, content modules and competence units. Relevant information on how to associate a professional certificate with a European Supplement is also provided.

The ontology is populated with information introduced by users using a web application (person and job profile), periodically updated information (certificate, training center, modules, competence units, job, employer, sector, occupation, skills and qualification) through the crawlers implemented (see Section 3), and public RDF or SKOS datasets for countries, regions and cities (e.g. NUTS), language level, driving license, etc.

4.3 Quality Evaluation Approach

The aim of our approach is to demonstrate that the quality and customization of search and recommendation results can be improved through the generation and use of ontologies. In particular, our purpose is showing that the quality of the underlying ontologies influences the performance of the quality obtained from the system. In our case, the knowledge domain is focused on recommending different training itineraries based on the user's profile as a starting point, the desired occupation to be reached and data from external sources (e.g., job offers, training courses, certificates, etc.).

Since our ontology has been built by hand on the foundation of the ESCO ontology model, reusing ontologies and vocabularies for the representation of certain concepts, adding new concepts and relationships to fill gaps of knowledge and gather a richer domain representation, and using external sources to populate the ontology, there is a need to evaluate the resulting ontology to ensure it meets certain quality criteria. The quality of this ontology will certainly affect the effectiveness of the DETECTA system.

In this context, our approach to address the ontology quality evaluation is using existing evaluation tools (e.g., *OOPs*, *OntoQA*, *OntoMetric*, *OntoCheck*, etc.), based on different metrics, dimensions and methodologies. This will allow checking, identifying and improving general errors that could have been committed during ontology building (e.g., lack of domain or range in the properties, fusion of different concepts in the same class, etc.). Then, we propose to evaluate the quality of the ontological model built by hand (in our case, the enriched ontological model of ESCO) regarding the resulting ontology generated through existing automatic matching tools and techniques, and taking as a starting point the same ontologies of origin. In addition, the performance of the automatic matching tools will be also evaluated by considering the results obtained from the search and recommendation system, where the enhanced ontology is used. Moreover, it could be evaluated how other existing ontologies of the analyzed application domain (e.g., HRM), as input from these automatic matching tools, can influence the performance of the system.

In order to evaluate ontology quality, dimensions and metrics will be adopted according to the classification presented in (Zaveri et al., 2015), such as accuracy, consistency, completeness, relevancy, etc. In addition, within our ontology-quality evaluation approach, we propose new metrics (e.g., metrics related to reputation systems) that can envision the develop-

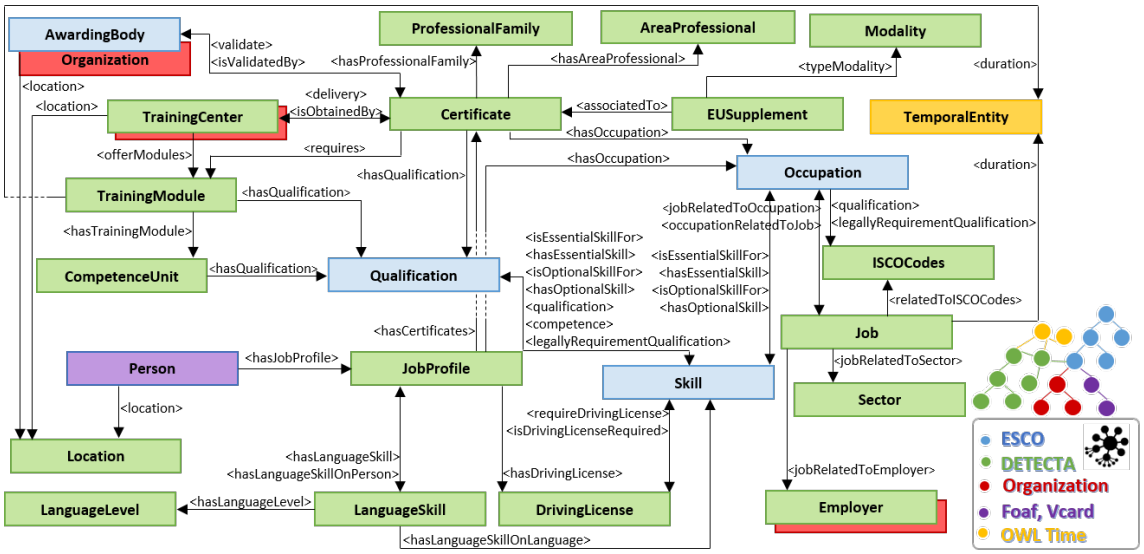

Figure 3: Main classes and relationships of the built enriched ontology.

ment of new models that promote quality, by analyzing the context and factors that affect quality in real problems in organizational or institutional domains for better decision making and achievement of results. Effectiveness and best results rely on the high-quality ontology, and although in some cases the manual construction of a quality ontology is not feasible, it is an aspect to take into account in systems that turn out to be critical.

5 CONCLUSIONS AND FUTURE WORK

In recent years, a large amount of data has been generated and stored at increasing speed as a result of the digital transformation and the appearance of the big data and its new features. How to provide quality results become a critical issue and an important key to support decision-making and to address problems at the business level. In this paper, we presented our work-in-progress related to the methodology followed to build an enriched version of the ESCO ontology, based on standards to enable higher quality results in a real-life scenario related to labour market as a case study. In this context, the DETECTA search and recommendation system can take advantage of ontologies capabilities. Furthermore, we outlined a new approach to evaluate how the performance of the search and recommendation system depends on the quality of the built ontological model.

Our next steps involve the implementation of the designed DETECTA architecture, the use of existing evaluation tools to address the improvement of the hand built ontology, and the evaluation of the enriched ontology model regarding the resulting ontology, generated through automatic matching tools. In addition, the evaluation of the search and recommendation system performance where the built ontology is used, the adoption of relevant quality dimension and criteria for the evaluation, and the proposal of new metrics to foster higher quality and better results in the analyzed context. As future work, we would like to further research the generation of models that promote data quality through the use of semantic technologies, based on systems with large data volumes and from heterogeneous sources for different business and institutional domains. Thus, these models could be used for intelligent data analysis and management, value extraction and decision making.

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