IT Skills Ontology

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Abstract

With the advance of technology, the jobs in the Information Technology (IT) area have increased, contemplating more and more new skills. Nowadays, it constitutes a problem in the recruitment field once there is no standard for all of those IT skills. As a consequence of this lack, it became hard to understand/assess if a candidate is, or not, the right match for a specific job and also to describe the job itself.

The chosen approach for overcoming this problem was to create an ontology for IT Skills, which should identify, conceptualize, and relate all the skills and jobs in the IT domain. We performed a Systematic Literature Review to learn more about ontologies in the field of IT and the methodologies for their development and evaluation to help us constructing an ontology for IT skills. The development, demonstration, and evaluation of the IT Skills ontology were guided by the Design Science Research methodology and conducted in a professional environment, mainly in a company that is dedicated to recruiting IT professionals. Using the data from the Systematic Literature Review, it was chosen and applied the Methontology methodology for the development. In order to evaluate the developed ontology, three approaches were used: Competency Questions, Experts Assessment, and Talent Advocate Specialists Interviews.

Through the assessment of the IT Skills Ontology, it was possible to conclude that its application is useful and brings advantages to the specialists, by facilitating the curation process and by making it easier and faster, especially for less experienced IT recruiters.

Keywords: Ontology, Ontology Development, IT Skills, IT Skills Ontology, Ontology Evaluation, IT Recruitment

1. Introduction

With the advance of the world and the appearance of new technologies, computer science conferred to the word ontology a different purpose compared to the philosophic one[24].

In the computer science field, an ontology is a graph structure to present knowledge capable of representing real world domain artifacts [17]. Ontologies are an essential part of Semantic Web and are even "considered as its backbone"[30]. They provide a formal way to represent knowledge [24], representing the relation between the different concepts in a way that both people and machine could understand/share it.

In that sense, ontology is a way to conceptualize, define and specify a certain domain in order to provide shared understanding about it [38]. It is possible to perceive ontologies as "thesauruses describing galaxies of concepts (stars) and features (planets) held together by semantic gravitation weighted by similarity or proximity"[1].

The computer science ontologies are used in different fields like biology[31], health[15], information management[25], semantic web[8], data science[6] among other fields, with the promise of performing a formal and complex representation of a domain of knowledge including the concepts, their definitions and all the relations between them [24] in a way that can decrease the information complexity and make it easier to understand.

Nowadays, with the web and technology present in all of everyone' routines the field of jobs and careers in IT is expanding exponentially, which constitutes a problem because there is still no official standard for assessing and categorizing IT skills [33], containing the different skills, their relations and the jobs profiles in this field. This lack generates difficulties to perform a better match between the job's requirements and the candidate's skills. The recruitment process became a way more difficult for the companies that have problems on understanding the right candidates for the different types of

[1] https://caminao.blog/knowledge-architecture/ontologies-models

job and describing the job requirements[2].

Different organizations are already trying to deal with this problem such as ESCO[3] (European Skills, Competences, Qualifications and Occupations) that already started to categorize and conceptualize the different jobs and careers and the correspondent skills to each one, and ESCoE (UK)[4] that made a taxonomy of the skills required for different jobs.

Both approaches (ESCO and EScoE) work like a taxonomy since they conceptualize and relate the skills hierarchically on the different jobs but they don't relate the skills between themselves and don't identify and specify all the kind relations between the different jobs and skills.

The chosen approach to solve the lack of standards for assessing and categorizing IT skills is to design and develop a comprehensive ontology of IT skills. The choice of this approach was made because an ontology allows us to define, conceptualize, categorize the different skills of IT area and to relate all the concepts, truly representing the knowledge involved.

In order to chose the best methodology for the ontology's development and evaluation, we, previously, carried out a Systematic Literature Review (SLR) based on Kitchenham's Procedures for Performing Systematic Reviews [21]. So as to develop and evaluate the IT Skills ontology's project in an organized and consistent way, we followed the guidelines provided by the Design Science Research [19] methodology.

This project, the development, demonstration and evaluation of the ontology, was conducted on a professional environment, integrated in a company, which is dedicated to matching the best tech professionals to the right companies all around Europe. It was decided that, due to being the most valuable for the company context, the ontology developed would cover only the hard/technical skills related to the IT Development jobs (for example: Backend Developer, Frontend Developer, etc...). So, the data used for the construction of the ontology was real data, mostly from the company in which this project was inserted. So as to develop and evaluate the IT Skills ontology's project in an organized and consistent way, we followed the guidelines provided by the Design Science Research methodology. The developed ontology was applied to the curation field, integrated in the recruitment process, of the company where the project was developed. Three approaches were used to evaluate our ontology: Competency Questions, Users Interviews and Experts Assessment.

[2]https://www.4cornerresources.com/blog/the-challenges-of-it-recruiting-how-to-overcome-them

[3]https://ec.europa.eu/esco/portal/skill

[4]https://data-viz.nesta.org.uk/skills-taxonomy/index.html

2. Theoretical Background

2.1. Ontology Definition

More recently, in computer science, ontologies have followed the same principles that in philosophy but with a different purpose. Working like a technology, ontologies have the purpose of modelate a domain in order to make it readable and possibly reasoned by a software [29].

Ontologies perform an important role in knowledge representation and reasoning [11]. Over the years many authors gave their definitions for ontologies, for example:

- "the term used to refer to the shared understanding of some domain of interest" according to Uschold and Gruninger[38];

- "a formal representation of the knowledge by a set of concepts within a domain and the relationships between those concept" by Man[24];

- "a formal, explicit specification of a shared conceptualization as stated by" Studer et al.[34].

In our work we follow a combination of the definition proposed by Man[24] and Uschold and Gruninger[38] because we believe that ontologies are a formal representation of a domain of interest through a the definitions and relations between the concepts of that domain, as a way to achieve shared understanding.

2.2. Ontology Development

With the increasing use of ontologies in computer science, several methodologies have been proposed for their development. According to the literature, different surveys[18][5][1] on methodologies for the development of ontologies have exposed some common methodologies, namely:

- Methontology [9];
- Enterprise Model Approach [37];
- TOVE [14];
- IDEF5 [28];
- Ontology Development 101 [27];
- On-to-Know (OTK) [35];
- NeOn[36].

Just as there are diverse methodologies for ontology development so do are different tools to help in the development process. According to the literature[42][41], it was possible to find that some of the main tools used for ontology development and management are Protégé/Protégé 2000, OilEd, OntoLingua, Apollo, OntoEdit, RDFedt, WebOnto, WebODE, KAON, DOE (Differential Ontology Editor), ICOM, Medius Visual Ontology Modeler, LinKFactory Workbench and K-Infinity.

2.3. **Ontology Evaluation**

Ontologies Evaluation is a crucial to verify if the ontology developed meets the requirements and if it satisfies the objectives for which it was built. Ontology evaluation can be understood, according to Goméz-Pérez[12], as a "technical judgment of the content of the ontology with respect to a frame of reference during each phase and between phases of their life cycle" including ontology verification, which "refers to building the ontology correctly", and ontology validation, which "refers to whether the meaning of the ontology definitions really model the real world".

According to Hlomani et al.[16] ontology evaluation must focus on two main perspectives: Ontology Correctness and Ontology Quality. Vrandecic[40] also included Organizational Fitness/Commercial Accessibility as an important metric to take in account during the ontology evaluation. Organizational Fitness/Commercial Accessibility concerns the fit of the ontology in the respective organization to be applied.

According to Cruz and Raad[30] the existing methods/techniques for ontology evaluation are:

- Gold Standard;
- Corpus-based;
- Application/Task-based;
- Criteria-based.

Hlomani and Stacey[16], also reported some problems and difficulties with the evaluation of ontologies like the subjectivity of criteria, lack/subjectivity in thresholds and influences of subjectivity on the overall value of the measures/metrics. Already exists inductive approaches [16] to criteria selection based, for example, on competency questions[3], and deductive approaches to criteria selection that use metrics similar to software cohesion metrics have been defined to evaluate the different ontology elements.

2.4. **Skills in IT**

The concept of skill is huge and vague. So, it is important to understand the what is, in fact, a skill and what types of skills exist in the IT field.

Francis Green mentioned an approach, named "PES"[13], for the definition of the concept of skill, not only for IT field but in general. "PES" is an acronym which contains the three key features that a personal quality needs to be a skill, which are:

- **Productive** - using skills at work are productive of value;
- **Expandable** - skills are enhanced by training and development;
- **Social** - because skills are socially determined.

All of this key features are dependent of the role and the field of works of each person.

Although there is an illusion that in the IT area, specifically, the only skills that matter are technical skills, soft skills also play a decisive role throughout a career in this field [7]. So it is possible to divide skills in two types, hard/technical skills and soft skills. The technical skills are the skills provident from technical knowledge or training that it is obtained and improved through education or professional work and soft skills are attributes and qualities that are reflected on each person behavior and personality.

Regarding technical skills, in the work of Kong et al. [22], the five main categories used to organize them were Programming Languages (e.g. C/C++, Java and COBOL), Web Development (e.g. SQL, HTML and JavaScript), Database (e.g. Oracle, SQL Server and DB2), Operating System and Environments (ex. Unix and Windows 95/98/2000) and Networking (e.g. Windows NT and WAN/LAN). It was also found a soft skill, in this case, communication skill.

Laar et al. [39] carried out a SLR to understand, among other subjects, "which concepts are being used to describe the skills needed in a digital environment, go beyond mere technical use, and focus on 21st-century digital skills". As a result of this study, it was concluded that the concepts are approaching skills related to knowledge or content, suggesting the approximation and mixing between technical skills and soft skills, although in job advertisements still prevail in technical ones.

The skills of IT professionals are, during the recruitment process, the key element in establishing the connection, or match, between a candidate and a job, where a perfect candidate-job combination includes the match between both soft and hard skills. Although, the majority of the job advertisements mainly focus on technical skills [26] mostly technical skills from different areas and types [22].

In this master thesis we focused our work on hard skills, and we will use the "PES" approach to check which of the found concepts can be classified as skills.

2.5. **Related Work**

In the literature, we found some valuable research regarding the development of ontologies for IT skills and others that used the IT skills ontologies as way to achieve a certain purpose.

Corrêa Leão et al. [23] developed a solution to face the difficulty of organizations "to attract, keep and manage talents". For this solution, the authors decided to develop an ontology about the competencies of IT professionals. They identified several

possible scenarios to the use of the ontology and defined certain questions that, in the end, the ontology must able to answer. This ontology focus on the management of the IT professionals' competencies/skills for Human Resources in IT Organizations. In 2016, Gavrilova and Laird [10] developed a practical ontology for IT skills, also for a human resources knowledge management system. They start by building a glossary of IT Skills and Knowledge and develop the ontology over it. It was possible to observe that the general ontology developed includes different categories, with sub-categories of the IT application areas with different types of relations and more specific skills inside them.

With a quite different purpose, in 2013, Singto and Mingkhwan [33], have noticed that even there are a lot of different Careers in IT, these are not stored in an "hierarchical structure" which makes the search performance decrease. To solve this, authors developed the IT Careers Ontology (ITCO) that is composed by three main parts: IT Career Category, IT Skill and IT Education. The IT Skill part is composed by different areas that aggregate different skills. In this paper is also proposed, semantic search using this ontology that revealed results linking IT skills to IT Careers.

More recently, in 2018, due to the increasing use of the online job search and talent procurement, Balachander and Moh [2] decided to use ontologies to find similarities between skills as a way to solve searching and matching problems associated with the e-recruitment. They calculate the scores between several skills using different approaches, and it was possible to relate that, comparing to human evaluated scores, the system has a better performance.

Khobreh et al.[20] also proposed an ontology, not for IT skills but for job knowledge in general. This ontology intends to identify people' lacks in the knowledge domain in relation to the required tasks for a specific role/type of job. It represents three main parts: Knowledge, Task and Competence. The Task and Competence are related as the Task requires Competence and the Competence enables Task. And the Knowledge is related to the Competence as the Knowledge qualify Competence and the Competence requires Knowledge.

Although there are few studies specifically related to IT skills ontologies, it is possible to verify the advantages of their uses by analyzing the above cases. Some lack with the studies that we analyzed are that they are quite general and, because of that, they become incomplete. In some of the papers, like the Corrêa Leão et al. work[23], the relationships between the skills themselves is not defined/taken into account. As the IT area is constantly expanding some of the analyzed papers do not present some of the most recent IT skills.

3. Research Problem

According to the DSR methodology, this Chapter corresponds to the "Identification of the Problem and Motivation" step.

Nowadays, with the digital transformation, IT is performing an important role in people's daily lives and as a consequence of this strong presence of IT, the demand of companies for professionals in this area has increased.

It was possible to understand that the process of recruitment of IT professionals is growing faster[5]. IT is a big area, full of different subareas, which require different skills and competences inside it and, due to that, it is not simple to find the right person for the right job [32]. The professionals of IT have a lot of different profiles and do not fit in every role, so this recruitment process needs to be performed very carefully, paying attention and assessing the different skills that the person has. It is important to understand the skills prerequisites of job to find the right candidate to execute it and improve job performance[20].

In many different companies, the old recruitment techniques cannot totally satisfy this need anymore, so a lot of companies started to adhere to new ones, such as e-recruitment. E-recruitment process intends to find the match between the professional talents and the jobs in a faster and more efficiently way comparing to the one performed by human experts by hand. To allow this kind of applications of e-recruitment to work with its full potential and efficiency, is needed to incorporate the knowledge of the experts in the systems in way to make it scalable and currently there is no standard for conceptualize and categorize the skills of the professionals in IT field in order to achieve make possible to transmit the knowledge of the human experts to the systems.

With the absence of a way of organize and categorize the skills in IT, the e-recruitment is time consuming and less efficient, leading sometimes to unsuccessful signings due to incompatibilities of the professional with the role to perform or the company itself (for example constraints of location, language or internal environment). Not having an hierarchical and well defined structure for IT Skills the specification, search and match between the right job and the right candidate do not "acquire satisfactory search results"[33].

In the particular case of this project, which was conducted on a professional environment, in a company of candidate-driven tech careers marketplace, it was possible to notice that there are some phases of the recruitment process that are conducted by

[5]https://economics.ubc.ca/news/2018/the-future-of-jobs-is-in-i-t-ubc-economist-studies-rise-of-information-technology/#.XgVWvNb7RQI

people that are not IT professionals. These professionals do not have the same knowledge and insights as the IT professionals about the IT skills domain, reinforcing the need of structured information about the skills used in the different the IT fields.

So, in summary, we can conclude that the problem for this research is that **there is a lack of a coherent and comprehensive approach for conceptualizing, categorizing and relating skills of the professionals in IT field**, namely in IT recruitment, **that helps matching the right candidate to the right job**.

4. Development of the IT Skills Ontology

In order to create and develop our proposed ontologies, we chose the Protégé tool since it is. Moreover, according to Corcho et al.[4], it allows us to follow the Methontology methodology.

The ontology development activities followed the Methontology Methodology. Methontology begins with the "Planning" phase, for defining the reasons to develop the ontology and their uses. As it was exposed in Section 3, the problem of this research is the **lack of a coherent and comprehensive approach for conceptualizing, categorizing and relating skills of the professionals in IT field**, which causes difficulties on recruitment processes and on job/candidate matching.

In this research we developed an ontology for IT skills that can be used to help in recruitment processes. It was decided that only technical skills, regarding IT Development, such as programming languages (Java, Ruby, etc.), software tools (PostegreSQL, MongoDB, etc.), frameworks (Ruby on Rails, React.js, etc.) and libraries (SciPy, NumPy, etc.) would be considered in this ontology and, consequently, the jobs in which technical skills are decisive. Although soft skills are also relevant to the standardization of jobs and profiles of IT professionals, these were out of the scope of this research since they are much more subjective.

The following step is "Conceptualization", where a conceptual model is achieved. Conceptualization activity, from Methontology, is divided in eleven activities, presented in Figure 1.

In the first task we developed a glossary containing all the relevant terms for the IT Skills Ontology with the respective Type and Description. Most of the skills were extracted from the IT recruiting company's database and complemented with the main terms founded on the leading e-recruitment websites. In order to guarantee the consistency of the extracted skills, we only added to the glossary those that, being technical skills, fulfill all the requirements of the PES approach [13].

After the glossary of terms is concluded we build,

Tasks	
Task 1	Build glossary of terms.
Task 2	Build concept taxonomies.
Task 3	Build ad hoc binary relation diagrams.
Task 4	Build concept dictionary.
Task 5	Describe ad hoc relations.
Task 6	Describe instances attributes.
Task 7	Describe class attributes.
Task 8	Describe constants.
Task 9	Describe formal axioms.
Task 10	Describe rules.
Task 11	Describe instances.

Figure 1: Conceptualization Activities.

we should create, as stated on the second Task, the concept taxonomies obtaining a concept hierarchy. We decided to divide the concepts in two main categories:

- **IT Skills** - abilities, knowledge and talents regarding to the use, development, architecture and management of technology.
- **IT Job Areas** - main job areas in the IT field.

In the third task we expose the relations between the different concepts. The relations between the different job areas of IT Development and the different types IT Skills and the relations between the IT skills themselves are represented in Figure 2.

The fourth task, consists in developing a dictionary of concepts, which describes the terms of the IT Skills ontology from the glossary of terms, containing all the domain concepts, their relations, their instances, and their class and instance attributes. This activity was performed with the help of the Protégé ontology editor.

The Table 1 concerns the fifth task of the Conceptualization phase, describing the ad hoc relations of the ontology. For each ad hoc binary relation, its name, the source and target concepts, its cardinality, and its inverse relation is specified.

The relations of Specialization are represented by superclasses. For example, Frontend Development is a particular kind of IT Development, so the IT Development is the superclass of Frontend Development. The relations regarding the uses of IT Skills by IT Developers, like using a certain framework, library, engine or programming language, work as Used By relationships, once it represents the use of the different types of skills by the different IT professional roles.

Table 1: Description of ad hoc relations of the IT Skills Ontology.

Relation Name	Source Concept	Source Cardinality	Target Concept	Inverse Relation
is framework of	Frameworks	N	Programming Languages	has framework
has framework	Programming Languages	N	Frameworks	is framework of
is library of	Libraries	N	Programming Languages	has library
has library	Programming Languages	N	Libraries	is library of
used with	Programming Languages	N	Programming Languages	used with
similar to	Engines	N	Engines	similar to
uses	IT Development	N	IT Skills	used in
used in	IT Skills	N	IT Development	uses

The relations of being a framework/library of a certain programming language work as Serving relationships because they represent the ability of that an element provides its functionality to another element.

The "Used with" relations, between two programming languages, is used as an Influence relationship, it represents that an element affects the implementation of another element. The "similar to" relation works as an Association relationship, and it means that a certain Engine/tool have the same or similar functionalities that another one.

In the sixth task, the instance attributes already on the concept dictionary are described in detail in an attribute table.

The seventh and eighth tasks were not performed since they are not applicable in the scope of the IT Skills ontology as class attributes or constants were not used.

In the ninth task, the formal axioms are described with properties such as name, natural language description, the first-order-logic expression of the axiom, and other components that axiom refers to. In IT Skills ontology, this axioms were described with Protégé tool.

The tenth task is about describing rules. This task was performed using the Protégé tool and verified by running the Pellet reasoner.

Once the all the concepts, attributes and relations are established we defined the relevant instances (eleventh task).

It is important to notice that in our development we did not perform the "Formalization" and the "Implementation" activities, once Protégé allowed us to automatically implement the conceptual model developed, in OWL (Ontology Web Language).

At the end of the execution of all these development steps proposed by Methontology we obtained the final IT Skills Ontology (presented in Figure 2).

5. Demonstration

This master's thesis was applied in a professional environment, integrated in a company that is dedicated to matching the best tech professionals to the right companies all around Europe.

Through the company's online recruitment platform, the potential candidates are able to search the different jobs available and choose to apply for those jobs that match their interests. The recruitment process begins when a candidate applies for a certain job. These applications are then sent to specialists in order to be curated by the company's talent specialists. However, is always up to the employer to select the applications he wants to analyze, and among these he chooses the candidates he wants to reject and the ones he wants to hire.

For demonstrate the use of ontology we applied it to the curation process.

Curation is an initial pre-screening process that ranks and creates an abstract for applications. It takes place before the application is delivered to the employer and is manually performed by a Talent Advocate Specialist that has the help of some pre-defined algorithms for the different dimensions. The outcome is not a badge of fit or to make upfront rejections. It is just a way to help employers streamline the hiring process. Ranking applications with the overall rate of 1-5 should only be interpreted as a suggestion to employers: start reviewing the 5-star applications and leave the 1 star for last. The candidates are evaluated according to different dimensions. Multidimensional Curation merely breaks the overall rate into several dimensions of evaluation and rates them independently. Another goal is to standardize, providing the Talent Advocate Specialists with a better way to maintain the consistency in their work.

One problem that the curation faces is the fact that the information is not always accurate since, sometimes, it varies from source to source, and do not follow a certain standard. Also, when filling the skills field, the candidate sometimes does not introduce all the skills that are aware of (more often, the more common skills are neglected). Therefore, it is sometimes very difficult to provide a trustworthy match score.

The application of ontology in the curation pro-

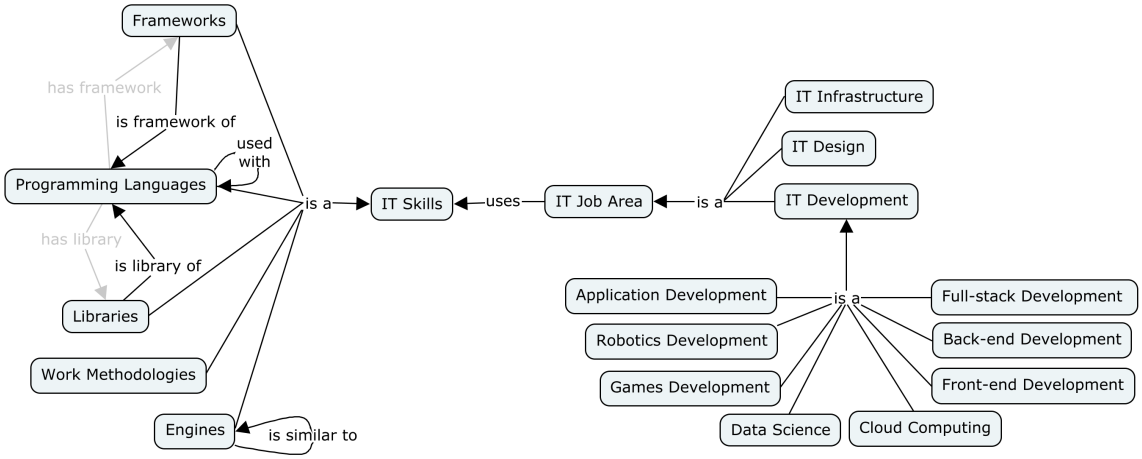

Figure 2: IT Skills Ontology's high level model.

cess consists on a field, called "Skills Report", on the platform used by Talent Advocate Specialists to assess the combination of a job and a candidate. It is a suggestion engine that transmits information about the relationships, direct or indirect, between the skills required in the jobs and the skills of the candidates. An example of the "Skills Report" in the curation process application is presented in Figure 3.

6. Evaluation

This Section corresponds to the evaluation phase of DSR methodology and presents the three approaches used to evaluate the IT Skills Ontology, that are:

- **Competency Questions (CQ)** - by applying this approach, we developed a set of questions that our artifact must be able to answer correctly. This evaluation also works as a way to check the artifact validity.
- **Experts Evaluation** - in this approach, we made a questionnaire to experts in the IT field using their opinion to evaluate the IT Skills ontology.
- **Talent Advocate Specialists Interviews / Task-based Evaluation** - in this approach, we applied ontology to the curation process, as done in the demonstration, and we evaluated the artifact based on the users' experience through interviews.

According to the evaluation performed to the ontology, there were achieved overall good results and several conclusions were reached.

Concerning the coverage of the ontology regarding the IT Skills domain, through the CQs, we could verify that it accomplished the requirements since it gave correct answers to all the questions, having a good coverage.

Diverse criteria was evaluated over experts questionnaires and user's interviews. Ontology was considered (both by experts and users), in general, effective, since it fulfills the intended effect, achieving its goal by helping the recruitment process, more specifically, the curation. It was also verified that the information provided by the ontology is easy to understand and that the ontology is a useful artifact for the curation process, although, according to most users, its application is more useful in less common areas of IT Jobs or for Talent Advocate Specialists with less experience.

It was also verified that the information provided by the ontology is easy to understand and that the ontology is a useful artifact for the curation process, although according to most users, its application is more useful in less common areas of IT Jobs or for Talent Advocate Specialists with less experience. It was also referred that it would be useful to use the ontology for other parts of the recruitment process, namely in the construction of jobs descriptions and requirements.

7. Conclusions

With this research we hope to had helped mitigate not only the research problem presented, but also to encourage new research so that the field of IT recruitment and IT Skills is increasingly studied, explored and improved, using the theoretical bases for obtain practical benefits for the professional world.

The main contributions of this master's thesis, were (1) the lessons and learning resulting from the SLR about ontologies related to IT, as well as the main methodologies for its development and evaluation and (2) an ontology for IT Skills, which brings together the main hard skills and the jobs that use them in the IT area.

The evaluation performed on the ontology allowed us to verify that the goal of this artifact was achieved. Through the use of the application of the

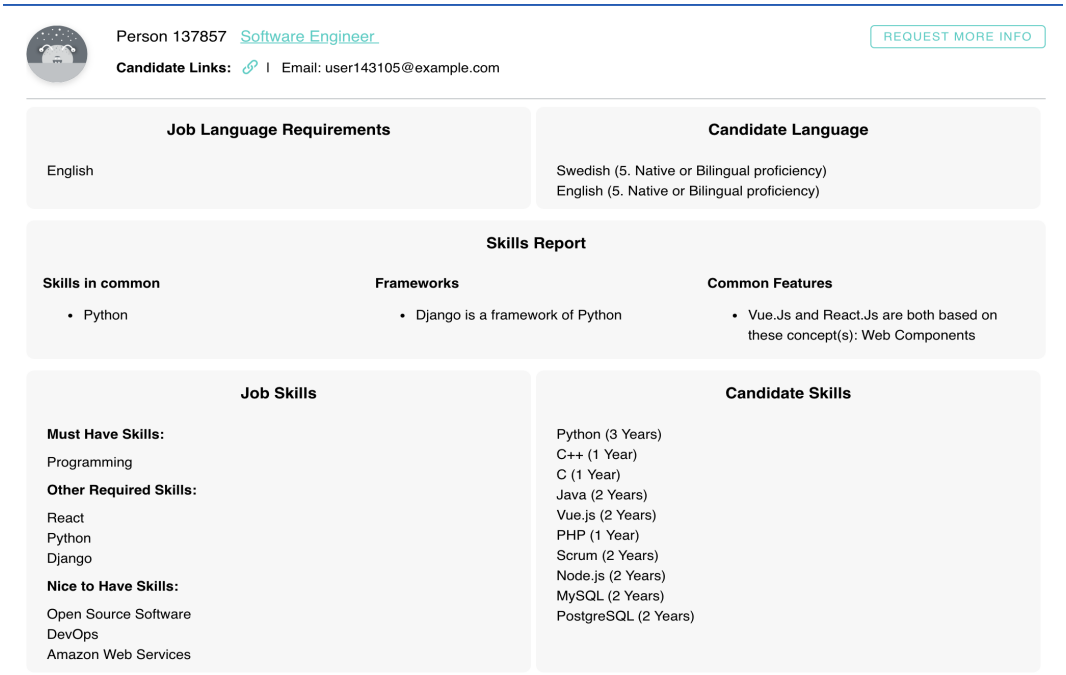

Figure 3: Skills Report example.

ontology in the context of recruitment, it was possible to conclude that the information related to the IT Skills' domain transmitted to curators is useful for them and helps them to be aligned with their work, obtaining better curations, especially for less experienced professionals or when skills and jobs are less common.

It was also possible to notice that there are some limitations regarding the developed work. Some of this limitations were:

- The IT Skills Ontology only covers the main jobs in the IT field and the respective hard skills and does not contain soft skills;
- The IT Skills Ontology does not cover the level of expertise/experience of the skills;
- It was only possible to apply the ontology in one of eleven possible scenarios:
- The maintenance and updating of the ontology is essentially performed manually.

According to the interviews with Talent Advocate Specialists and the questionnaires to Experts, we realized that some future steps would be desirable, both from a useful and professional point of view and from a scientific point of view, such as:

- Add to the ontology skills expertise levels;
- Apply the IT skills the ontology to the posting jobs providing skills suggestion and help define job requirements so that they are clearer and more specific, since this is the aspect most criticized by curators;
- Apply the IT skills ontology to the posting jobs validation and to the candidate profile validation;
- Apply the IT skills ontology to improve the search engine of jobs and candidates;
- Apply the IT skills ontology to the candidate sign up/update providing skills suggestion;
- Apply the IT skills ontology to provide smarter market insights based on the most wanted/used skills in the different areas;
- Add to the ontology more knowledge about less common skills and less technical areas;
- Introduce soft skills concepts in ontology;
- Align machine learning techniques with ontology so that it is more dynamic.

It is also important to ensure the maintenance and updating of the ontology, so that it continues to be useful and to transmit enriching information.

The last phase of the DSR methodology, is the communication of the results to the scientific community. Therefore, two papers were submitted to the scientific community: "A Systematic Literature Review on Ontologies Development and Evaluation Methodologies" to "Knowledge and Information Systems" journal (Q1) and "An IT skills ontol-

ogy for matching talent and companies" to "Information Technology and People" (Q1) journal. Both papers are currently awaiting results. The paper "A Systematic Literature Review on Ontologies Development and Evaluation Methodologies" contains the SRL carried out during the development of this master's thesis and the paper "An IT skills ontology for matching talent and companies" addresses the development, demonstration and evaluation of the Skills IT ontology.

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