Following up a case study for the Semantic Web

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ABSTRACT: The Semantic Web has been proposed as an infrastructure for handling the complexity associated with the problem of information overload on the Web. The use of semantic markup languages such as DAML to describe web documents enables the application of a variety of agent related technologies. They allow, for instance, intelligent, automated, and more efficient (web) services for searching, mining and maintaining information. These technologies leverage applications from e-commerce to knowledge management. This paper describes a case study based on the design and development of a Semantic Knowledge Portal for research projects to support R&D Knowledge Management for the TecComm Group, based on ontologies, web services and other features of the Semantic Web.

Keywords: Semantic Web, Knowledge Portals, Knowledge Management, Ontologies, Competence Questions.

RESUMO: A Web Semântica foi proposta como uma infra-estrutura para tratar a complexidade associada ao problema de sobrecarga de informação na Web. O uso de linguagens de marcação semântica, como DAML, permite qua tais informações sejam tratadas e utilizadas por agentes de software e outras tecnologias relacionadas. Esta utilização visa, por exemplo, o aumento da eficiência em serviços de busca, extração e manutenção destas informações, dentre outros. Estas tecnologias podem aumentar o potencial de aplicações em domínios que variam de comércio eletrônico a gerenciamento de conhecimento. Este artigo descreve um estudo de caso baseado no projeto e desenvolvimento de um Portal Semântico de Conhecimento para dar suporte ao gerenciamento de conhecimento do Grupo TecComm, notadamente no que se relacione a projetos de pesquisa.

Palavras-chave: Web Semântica, Portais de Conhecimento, Gerenciamento de Conhecimento, Ontologias, Questões de Competência.

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1. INTRODUCTION

Knowledge Management (KM) has become recently an important success factor [24] for several kinds of knowledge-intensive organizations, from enterprises to universities and research groups. However, implementing a KM initiative is both a hazardous and complex task. The TecComm Group – a research group at the Software Engineering Laboratory (LES) of the Catholic University of Rio de Janeiro - is composed by undergraduate, graduate and post-graduate students and researchers that carry on several state-of-the-art research projects on multi-disciplinary areas such as E-Business, E-Learning, KM and Multi-Agents Systems, just to name a few. Since the group is mainly composed by students and they are frequently completing their courses, the research team has an intensive turnover. This sometimes causes a lack of continuity on TecComm projects, since researchers' knowledge can be lost when someone leaves the group. These reasons make necessary a more comprehensive and systematic management of R&D knowledge.

This work presents a case study based on the design and development of a Knowledge Portal for research projects to support Research and Development (R&D) Knowledge Management based on ontologies and web services on the Semantic Web. This paper does not describe a methodology, method, or process for building Knowledge Portals, although it presents a particular mapping of ontologies into a model used by our framework for portals. The approach presented intends to show a way to integrate the actual web through knowledge portals and the Semantic Web through the mapping of ontologies into the models of the framework for portals. This way we can improve user participation in the construction of data that will be accessed by software entities, such as agents, in order to create new and inferred (meta) data.

The paper is organized as follows. Section 2 provides basic definitions of ontologies and the semantic web and can be skipped by readers that already have this background knowledge. Section 3 describes the design and development of the TecComm Semantic Knowledge Portal. In this section the Computer Science (CS) Research Projects ontology construction is briefly presented. We also present some examples of queries developed to test the expressiveness of the ontology. Still in section 3, the Portalware Framework, the hypermedia application framework used, is presented. Therefore, we briefly present the semantic layer and how the web services technology was used to provide semantics about knowledge content to software agents. Section 4 discusses related work and Section 5 presents some concluding remarks and future works such as the development of software agents to use the annotated data provided by the semantic layer.

2. ONTOLOGIES AND THE SEMANTIC WEB

According to Fensel [11], the traditional solutions to questions regarding KM have weaknesses in answering questions concerning search, data mining, information maintenance, and automatic generation of documents. Another problem related to KM is that people cannot share knowledge if they do not speak a common language [27].

Knowledge Management Systems (KMS) can treat these weaknesses using ontologies, which are a mean to achieve the desired common language. Ontologies generate common vocabulary and understanding about knowledge domains. This common understanding allows one to build documents with semantic annotations, which are the basic requirements to have a Semantic Web. Semantic Web is the present web with addition of formal semantic data representation.

The new TecComm web site will become a semantic web site, as its content will be explicitly represented via semantically annotated metadata, in order to facilitate information searching, extracting, and maintenance, and the automatic generation of documents.

2.1 Ontologies

The term Ontology has its origins in Philosophy, and it is related with the research about existence. In the Computer Science Community, one of the first references to the term can be seen in [18]. From the idea of reusing knowledge components in order to build knowledge based systems, Neches *et alli* used ontologies to define reusable knowledge components.

Since then, several communities are interested in research involving ontologies, such as natural language processing, information systems and intelligent integration information systems, among others. One of the most referenced definitions of the term is due to Gruber [13] "an ontology is an explicit specification of a conceptualization". In this definition, by conceptualization we can understand the concepts, objects and other entities which exist in an area of interest, and the relationships between them [12]. Borst [8] made a slight modification in Gruber's definition, and it seems more appropriated: "ontologies are defined as formal specifications of shared conceptualizations".

Following Borst's definition, we can infer that ontologies are important to software systems which aim to search or combine/integrate information from different communities. This is exactly the case of web information, where ontologies can allow the semantic representation of data. This representation will enable the production of semantic annotated information that can be used by web applications or software agents.

The use of ontologies by web applications or the ontology understanding and processing by software agents can be seen as a way of building more intelligent applications in a near future [26]. Besides that, it is desired that applications become more secure and confident based on trusted ontologies and inferred information. The Semantic Web will enable even more interesting functionality through complex logics and the exchange of proofs to establish trust relationships [14].

2.2 The Semantic Web

According to Berners-Lee [5 and 6], a definition to the Semantic Web could be: Semantic Web is an extension of the web obtained via the semantic addition to the present data format representation.

The main purpose of having a Semantic Web is making the web information understandable for humans and for software entities such as agents or components. In this sense, if the web content would be machine processable, web applications would have access to a huge variety of resources which could be processed and/or integrated in some way produces a valuable result to the user.

The present web is based on HTML (HiperText Markup Language), which allows human-human communication, because humans can understand its pages content. This characteristic restricts the use of other information retrieval techniques different from keyword based search. Benjamins *et alli* [4], presents the Semantic Web as a mean of treating the problem of information overload caused by the continuous web growth, in size, languages, and formats. In the Semantic Web, pages present not only a set of words, figures, tables and other elements, but the code and the structure of their meanings, allowing the electronic processing of it.

The web ontologies description languages (SHOE [35], RDF(S) [36], DAML+OIL [37], OWL [39,40,41,42]) make the Semantic Web possible. As they are based on XML, these languages are richest than HTML and they permit to represent the structure, the syntax, and the semantics of the web content. Some of them, like SHOE, DAML+OIL and OWL, permit to make inferences about concepts and relations between them.

In order to develop the Semantic Web, the information meaning must be machine understandable through the definition of rules to be applied to data and rules that define how these data will be transformed in another (meta)data. The use of ontologies is a key point to obtain these data after the creation of knowledge bases from semantic annotated web pages. This is done by using one of the languages quoted above. Because of that, the reduction of the computational effort and the increasing of the annotational effort would be a reality during the implementation of the Semantic Web. Aiming the production of annotated data in order to experience and evaluate the power of the Semantic Web technologies we developed a case study which is next presented.

3. THE TECCOMM SEMANTIC PORTAL DEVELOPMENT

One of the most important goals of the TecComm website is to facilitate sharing and maintenance of up-to-date knowledge about people who work at TecComm group. Nowadays, KM is becoming a critical success factor for several kinds and sizes of companies and institutions. It is a common sense to say that knowledge is the most important corporate asset. However, several companies had only implemented an incidental (and often unconscious) approach for managing corporate knowledge assets. More recently, those companies are realizing that, to be more productive, competitive and profitable they must improve the way those initiatives are being conducted.

KM can be defined as the effort to improve corporative and human effectiveness through the establishment of better connections [28] among people and knowledge inside and outside an organization. This encompasses not only providing universal knowledge and information access to employees but also motivating and supporting knowledge sharing among them. This effort can be built through a combination of cultural and organizational processes with information technology, since it is possible to acquire, to manage and to access knowledge available inside and outside the company. The Portalware Framework presented in section 3.2 is an attempt to help this complex task. Despite all this hype surrounding the KM term, KM is not a new idea. However, the fast web evolution and the development of new communication technologies is making possible the creation of an environment where people and companies can disseminate, acquire, store and retrieve information related to their activities in a much more dynamic, universal and efficient way.

KM solutions should integrate formal, semi-formal and informal knowledge so as to make it easier to access, to share and to reuse the knowledge of an organization, improving individual and collective problem solving [29]. In this context, the knowledge need to be modeled and structured, then it becomes possible to establish all the relations among its different expressions. Knowledge Portals [22] are proving themselves as effective tools to make this knowledge available all wide the company. Ontologies also play a role in this context since they present the semantics of concepts. But just creating an ontology does not guarantee that it is representative, so it is also important to evaluate how expressive this ontology is.

In the next sub-section we put these things together in order to get the better of each one, through the implementation of the TecComm Semantic Knowledge Portal. The first step was the creation of the CS Research Projects ontology, then the ontology was mapped into the Portalware Framework models followed by the implementation of the Semantic Portalware Web Service which provides annotated (meta) data about TecComm researchers. The semantic annotation allows web applications and software agents to use the TecComm (meta)data in order to infer other data, and provides services to TecComm group or to the research community in general as will be presented in section 5.

3.1 The CS Research Projects Ontology

To develop the CS Research Projects Ontology we used a "methodology" that addresses the issues of why one would build an ontology and which is based on declarative knowledge representation systems [43].

The ontology development started by searching for existing ontologies related to the CS research projects domain. Some ontologies were found and some of their concepts were reused. Since the beginning, the option of describing concepts using Portuguese, the native language of the authors, seemed natural and it showed as a mean of better understanding the domain. When the ontology was stable (version 0.9), the English version was made. All the versions can be accessed on www.teccomm.les.inf.puc-rio.br/daml/onts/.

The ontology was built from the very beginning, reusing some concepts from other ontologies. After deciding which concepts would be reused, and which ones would be key-concepts to build the ontology, some competence questions [25] were elaborated.

Competence questions are the ones which must be answered by the ontology or by inferences made by using the ontology. A list of terms we would like either to make statements about or to explain to a user (key-concepts) were: person, project, physical resources, scientific and technologic production, partners, sponsors and research area. From the key-concepts definition, others concepts were defined and a taxonomy was built. The competence questions formulation helped the process of finding new concepts and relationships between them. Some of these questions, related to the Project concept, are next presented:

Given a Project:

- which resources (physical and human) are associated to it?
- who are its coordinators?
- what are its scientific production?
- what are its technologic production?
- who are its sponsors?
- who are its partners?

An ontology can be characterized based on the use of competence questions about a particular domain. The ontology expressiveness is analyzed considering the set of formal queries constructed from the competence questions that the ontology can answer. The ontology should have a sufficient number of "axioms", concepts and relations in order to answer those queries. In the following sub-section we define and discuss how competence questions were used to evaluate the expressiveness of an ontology.

3.1.1 *Evaluating the Expressiveness of an Ontology through Competence Questions*

Evaluating the expressiveness of an ontology through the competence questions that it can answer can generate new concepts, relations and axioms. Competence questions can be defined in a stratified manner. There are atomic competence questions and complex competence questions which can be formed of atomic competence questions. Therefore, competence questions are classified according to the complexity of the queries generated from them. This complexity is verified according to the number of concepts and the "inferences" used on the query [25].

Atomic competence questions, also designated lower level questions, refer to only one concept in the domain. The queries generated from them are simple to formulate and the results/answers to these queries do not require any inference over other ontology concepts. However, more elaborated queries are needed to obtain results from a complex and intricate knitting domain, which leads to complex competence questions whose answers must provide results more concise and complete. Complex competence questions, or high level questions, use results/answers of competence questions of a lower level (atomic). Therefore, queries generated from complex competence questions use as input the results/answers of queries generated from atomic competence questions. The path followed by the composition of atomic queries in order to generate the complex query is what we also understand as an inference.

As it was presented, we first described the competence questions in natural language. In order to analyze the ontology expressiveness and to characterize the competence questions, they were formally described using RQL (RDF Query Language) [38].

According to Uschold, and Gruninger [25], an ontology is not well defined if all the competence questions that characterize it are atomic, that is, if they are represented by simple queries. Therefore, in order to develop a well defined domain ontology, it is necessary to create complex competence questions regarding the domain. Using this criterion to evaluate the well-definition of an ontology, we can assert that the CS Research Projects Ontology is well defined, since atomic and complex competence questions were developed. Next, queries based on (some of) the competence questions are presented as their classifications. As pointed before, the queries are formulated in RQL.

Given a project

1. Which resources (physical and human) are associated to it?

Meaning: Given a project, which physical resources are used by it and which people work, are responsible or coordinate it?

Used properties:

{Organization, Project, Laboratory}hasContact{Person}

{Organization, Project, EducationalOrganization}hasPerson{HumanResource}

{Project}hasResponsibleResearcher{Researcher}

{Project}hasLaboratory{Laboratory}

{Project}hasProduct{Product}

{Product}hasDocumentation{Documentation}

Query:

```
SELECT Y,Z,K,L,W
FROM
    {X}hasContact{Y}
    {X}hasPerson{Z}
    {X}hasResponsibleResearcher{K}
    {X}hasLaboratory{L}
    {X}hasProduct.hasDocumentation{W}
WHERE X like "Project URL"
```

Classification: This is a complex competence question. The query generated from it refers to the concepts Project, Product, Documentation, Person among others. The result/answer is not immediate, for example, to get the documentations of a project it needs to find first the products of the given project and then the documentations (physical resources) that describe the products.

2. Who are its coordinators?

Meaning: Given a project, who are the researchers responsible for it?

Used properties:

{Project}hasResponsibleResearcher{Reseacher}

Query:

SELECT Y

FROM {X} hasResponsibleResearcher {Y}

WHERE X like "Project URL"

Classification: this is an atomic competence question. The query generated from it refers only to the project concept. The result/answer is immediate, it doesn't need to infer any data since it only seeks for the value of the corresponding property in the project concept. As it can be seen, this query were reused in the first query presented.

At the beginning of the ontology development a set of competence questions were proposed. Here, due to space limitations we present just a few. After some refinements in the concepts, relations and axioms we started testing the expressiveness of the ontology through the competence questions. Although the CS Research Ontology showed itself expressive, we also felt the necessity to develop new competence questions since we understood better the domain. Next we present one more complex competence question as an example of this.

3. What are the products of a project and its sub-projects?

Used properties:

{Project}hasProduct{Product}

{Project}hasSubProject{Project}

Query:

SELECT Y, Z (SELECT Y1

FROM {Z}hasProduct{Y1})

FROM {X} hasProduct {Y}

{X}hasSubProject{Z}

WHERE X like "Project URL"

Classification: This is a complex competence question. The query refers only to the project concept, but the result/answer is not immediate. We need to "infer" which are the sub-projects of a project and then get the products of it.

After presenting the ontology development and the evaluation of its expressiveness, we present how the Portalware Framework was instantiated so users can access and manage the knowledge base, which will then be annotated by the Semantic Layer (which will be presented in section 3.3) following the ontology definitions.

3.2 The Portalware Framework

The Portalware Framework [19] was conceived and developed to automate the process of instantiation of Knowledge Portals. Knowledge Portals provide views onto domain-specific information on the WWW, so users can better find relevant and domain-specific information [22]. On the other hand, frameworks [10] are application generators that are directly related to a specific domain. Frameworks are created to generate applications for a specific domain based on the customization of flexibility points. In Portalware, the most important flexibility points that should be customized are implemented through the knowledge conceptual and interface model.

The use of ontologies in the development of knowledge portals allows the combination of functionalities that facilitate its use not even by humans but by software agents as well. Hypermedia applications play an important role on providing the interface through the development of a web-based knowledge portal, since they can be seen as systems that are built to function as part of a man-machine team. From the machine viewpoint, several techniques can be applied, from Databases and Knowledge Based Systems to Neural Networks and so on. On the other hand, the human uses a hypermedia paradigm to manage (access, maintain, edit) the stored knowledge. The hypermedia paradigm is also used to smoothly integrate the formal (machine readable) and informal (used by the human) knowledge representations [20].

As we have seen, to develop Portalware instances it is necessary to design two knowledge models (conceptual and interface) that will serve as the Framework input, so the desired Knowledge Portal can be generated. These models are inspired on OOHDM Conceptual and Navigational Models, described in [21].

The Knowledge Conceptual Model describes the structure of the knowledge that will be stored - regarding the related knowledge domain - through Object Oriented classes and its properties (that represent either simple attributes or relationships among classes). The model contains the domain conceptual structure, and carries no information about how it should be presented to the user nor how it has to be stored. This conceptual structure can be seen as the semantic information about the domain while the Knowledge Interface Model informs how the knowledge base can be accessed by the hypermedia application. Once these two models are designed and implemented, it is only necessary to start the generation process. All the facilities for search and knowledge base maintenance – to support tasks as feeding and editing information – are built-in in the framework and are automatically incorporated to the hypermedia application.

Having the definition of a domain ontology, the question faced was how to extract the Portalware Knowledge Model from this ontology in order to use the Framework and all its features to develop a Semantic Knowledge Portal. In this case study we used the CS Research Projects ontology as the ontology to develop the TecComm Knowledge Portal. Further in this paper we describe how a Semantic Layer was added to the Knowledge Portal to provide annotated data to software agents and applications that will be able to process the knowledge base.

The first step was to realize the ontology not as the DAML+OIL or RDF file that describes it, but as its original definition – a formal specification of a shared conceptualization. As seen before, ontologies are typically a vocabulary used to describe a certain reality, constituted by a set of concept definitions, relations among this concepts (described as properties) and explicit assumptions regarding the intended meaning of this vocabulary [31], [30]. The relations among ontology concepts can be either taxonomic (for example, a professor is a faculty and a faculty is a person) or non-taxonomic (a professor is responsible for a research project, a research project has some related products).

According to [30] an ontology structure (O) is a 5-tuple:

- O := { C , R , Hc , rel , Ao }, where:
- C and R are two disjoint sets whose elements are the concepts and relations, respectively;
- Hc is the concept hierarchy, that contains the taxonomic relations of the ontology;
- the function rel that relates concepts non-taxonomically;
- and Ao is the set of ontology axioms.

Since the Portalware Knowledge Conceptual Model is quite similar to the Object Oriented Model – despite some particularities that will not impact on this approach - a simple heuristic could be defined to guide the translation from an ontology described on the O structure to the Portalware Knowledge Conceptual Model structure:

1. First of all, the concepts of the O structure can be directly mapped onto classes in the Knowledge Model
2. The next step is to build the taxonomy of the Knowledge Model. This taxonomy can be entirely extracted from the Hc hierarchy of the O structure and must be described as a set of generalizations and specializations among concept elements. Since in the real world multiple inheritance can be clearly identified in several knowledge domains, all these taxonomic relations must remain in the Portalware Knowledge Model, described as parent-child relationships among concepts.
3. All the non-taxonomic relations among concepts must be mapped to Object Oriented relations among classes or being transformed in attributes. The guidelines to the knowledge engineer in order to decide whether to map a relation to an attribute or to a relation to another class are described on [19].

When the Portalware Knowledge Model was finished based on the domain ontology, the next step was to build the Knowledge Interface Model. As pointed before, this model describes how the knowledge base (structurally described by the Knowledge Model) will be presented through the hypermedia application to the users. The Knowledge Interface Model maps each concept to a node (what means that each instance of this concept will have a page dynamically generated to present its attributes) and each non-taxonomic relation among concepts to an edge (that will be presented as a link in both domain and range nodes). Taxonomic structure were used to generate navigational indexes for related nodes. Both links and attributes are presented with an appropriate and descriptive label, also informed through the Knowledge Interface model.

Both models are implemented in XML, according to Knowledge Conceptual Model and Knowledge Interface Model DTDs, described in [19]. The Portalware Framework generates SQL queries based on the Knowledge Conceptual Model so it becomes possible to generate the database that will store the knowledge base itself. It is also necessary to generate the HTML or XML templates that will be used for presenting the information described in the Knowledge Interface Model. In the current version of Portalware, the HTML templates have to be merged with JSP special tags that will indicate where attributes, links, labels and indexes have to be rendered in the page. These tags are implemented as JSP Taglibs [23] and are also listed in [19].

3.3 Building the Semantic Layer

In order to provide data to the Semantic Web, these data must be described in a semantic markup language, such as DAML+OIL. PortalWare provides data in XML and HTML formats which lack on semantics. The creation of a semantic layer would solve this problem, providing means for content annotation and the creation of the Portalware Knowledge Semantic Portal Infrastructure. The semantic layer was implemented as a web service named Semantic Portalware Web Service (SPWS) which converts the PortalWare's data to DAML+OIL documents.

SPWS uses information from the Portalware relational database and from the CS Research Projects ontology in order to generate semantically annotated metadata in DAML+OIL language. This data can be accessed through the Web by different autonomous entities such as software agents and components.

The Portalware Knowledge Portal is accessible through Web browsers and the SPWS comes to improve the portal offering semantic information through the markup of the data stored on the knowledge base using DAML+OIL. To accomplish that it access the Portalware database and the ontology definition that generated the Portalware Knowledge model.

4. RELATED WORK

There is a wide range of related works to this one, to name a few: Semantic Web Portals initiatives, regarding mainly Semantic Web Portals methodologies, portal frameworks development and related technologies.

Concerning to semantic web portals frameworks and methodologies, the SEAL (and SEAL-II [15], the latest version) approach can be considered one of the most important examples. SEAL authors have developed a generic approach for developing semantic portals that exploits semantics for providing and accessing information at a portal as well as constructing and maintaining the portal [Maedche et al., 2001]. Ontologies constitute the foundation of SEAL (SEmantic portAL) approach. The origins of SEAL lie in Ontobroker [9], which was conceived for both semantic search and sharing of knowledge on the Web [3]. Those technologies where applied in the AIFB Semantic Portal. The AIFB ontology models the domain of research topics and administrative tasks at the Institute AIFB. This ontology forms the basis to annotate documents in order to enable semantic access to them [1].

The main difference between SEAL approach and the one presented in this paper is that while the first is mainly based on ontologies, the later is also based on a well consolidated hypermedia application framework (Portalware) and relies on web services to present semantic annotation for stored data.

The RDF Editor [32] is a graphical tool for creating RDF within an HTML document. According to the authors, the RDF Editor combines WYSIWIG HTML editing with a semantic web portal for guided semantic markup using distributed vocabularies. The main goals of the RDF Editor are to provide the user with a environment in which he can create his web page with few markup hindrances and to markup it with minimal knowledge of

RDF terms and syntax using existing ontologies. A Semantic Web Portal consolidates these pages and allows knowledge access, search of web pages and submission of content. It uses a different approach since each user can also create its own semantic markup. Despite being a very interesting approach, this is not an interesting way to perform in TecComm Group KM since we intend to provide a shared conceptualization of Research Projects concepts among TecComm Researchers, what was achieved with the proposed ontology.

5. FUTURE WORK AND FINAL CONSIDERATIONS

During the evaluation of the expressiveness of the CS Research Project ontology we observed that it has a sufficient number of axioms, taxonomic and non-taxonomic relations that makes the ontology able to answer the initial proposed competence questions. However, we could also find some concepts that were defined and not used to answer any competence questions.

Software agents and web services are being developed so as to perform automatic tasks based on the semantic data provided by the SPWS. These agents may substitute TecComm researchers in a plenty of tasks such as the generation of scientific production reports, the recommendation of self-study roadmaps based on group's publications to newbies and the formation of research project teams just to name a few.

The Semantic Knowledge Portal infra-structure developed for this work will also be applied to other research groups first in the CS domain and after in other domains, when new ontologies will have to be developed. This can help us to analyze how different groups use the Knowledge Portal so as to identify weaknesses and strengths of our approach. Issues regarding the semantic portal scalability, performance and security also need further development.

We presented in this paper a case study describing the design and developments of a semantic knowledge portal for the TecComm Group. We have shown why it was important to implement a KM initiative for this research group and how we used ontologies, semantic web technologies, web services and a hypermedia application framework to achieve this. We also exposed some future applications which can be developed in order to evaluate the *power* of the Semantic Web.

Once the TecComm Semantic Knowledge Portal is totally implemented and deployed, TecComm researchers are expected to share information much more frequently, providing up-to-date information about their projects, about themselves and about associated technologies. The development of new software agents and web services will leverage the goals accomplished with this work, adding new functionalities so users can better access and maintain R&D knowledge.

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