Semantic Reasoning Method to Troubleshoot in the Industrial Domain

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***Abstract*—Currently industrial information provides even more granular information through unit and equipment databases, which provide details about installed equipment, including models, designed capacity, throughput, and start up/shutdown dates for turbines, generators, refining equipment, etc. All these data and information are stored in digital repositories, digital archives, and business Web sites. Access to these collections poses a serious challenge. The present search techniques based on manually annotated metadata and linear replay of the material selected by the user do not scale effectively or efficiently to large collections. This can significantly reduce the accuracy of the search and draw in irrelevant documents. The artificial intelligence and Semantic Web provide a common framework that allows knowledge to be shared and reused in an efficient way. In this paper, we propose a comprehensive approach for discovering information objects in large digital repositories based on analysis of recorded semantic metadata and the application of Case Based Reasoning technique. We suggest a conceptual architecture for a semantic search engine. We have developed a prototype, which suggests a new form of interaction between users and digital enterprise repositories, to support efficient share distributed knowledge.**

Keywords- Case base Reasoning, Ontology, jColibri, Semantic Interoperability, Artificial Intelligence.

I. INTRODUCTION

Nowadays an enormous quantity of heterogeneous and distributed information is stored in BB.DD, Web sites, digital storehouses, etc. Digital Industry Repository (DIRs) are online databases that provide a central location to collect, contribute and share knowledge resources to use in the industrial domain. Mechanisms to retrieval information and knowledge from digital repositories have been particularly important. DIRs present centralized hosting and access to content. DIRs provide the ability to share digital objects or files, the permissions and controls for access to content, the integrity, and intellectual property rights of content owners and creators.

In the traditional search engines, the information stored in DIRs is treated as an ordinary database that manages the contents and positions. Results generated by the current searches are a list of results that contain or treat the pattern. Although search engines have developed increasingly effectively, information overload obstructs precise searches. Thus, it is necessary to develop new intelligent and semantic models that offer more possibilities. Our approach for realizing content-based search and retrieval information implies the application of the Case-Based Reasoning (CBR) technology and ontologies. The objective here is thus to contribute to a better knowledge retrieval in the industrial domain.

There are researchers and related fields works, which include intelligent techniques to share information such as [1] which describes the application of intelligent systems techniques to provide decision support to the condition monitoring of nuclear power plant reactor cores. An intelligent image agent based on soft-computing techniques for color image processing is proposed in [2]. Huang et al. [3] propose an intelligent human-expert forum system to perform more efficient knowledge sharing using fuzzy information retrieval techniques. Yang et al. [4] present a system to collect information through the cooperation of intelligent agent software, in addition to providing warnings after analysis to monitor and predict some possible error indications among controlled objects in the network. Gladun et al. [5] suggest a Semantic Web technologies-based multi-agent system that allows to automatically control students' acquired knowledge in e-learning frameworks.

The meta-concepts have explicit ontological semantics, so that they help to identify domain concepts consistently and structure them systematically. In [6] authors propose a construction safety ontology to formalize the safety management knowledge. Bertola et al. [7] present the building blocks for creating a semantic social space to organize artworks according to an ontology of emotions, which takes into account both the information two ancestral terms share and the probability that they co-occur with their common descendants. In [8] authors present an approach, which allows users to semantically query the BIM design model using a domain vocabulary, capitalizing on building product ontology formalized from construction perspectives. Zhang et al. [9] propose a framework to quantify the similarity measure beneath a term pair, which takes into account both the information two ancestral terms share and the probability that they co-occur with their common descendants. In [10] authors present a method for selecting a semantic similar measure with high similarity calculation accuracy for concepts in two different CAD model data ontologies.

There are a lot of researches on applying Artificial Intelligence (AI) and semantic techniques to share knowledge. In this paper, we present a full integration of AI technologies and semantic methods during the whole life cycle and from the industrial point of view. Our work differs from related projects in that we build ontology-based contextual profiles and we introduce an approaches used metadata-based in ontology search and expert system technologies. This paper describes semantic interoperability problems and presents an intelligent architecture to address them. We concentrate on the critical issue of metadata/ontology-based search and expert system technologies [11]. More specifically, the main objective of this research, is search possible intelligent infrastructures form constructing decentralized public repositories where no global schema exists. For this reason, we are improving representation by incorporating more metadata from within the information. The objective has focused on creating technologically complex environments industrial domain and incorporates Semantic Web and AI technologies to enable precise location of industrial resources.

The contributions are divided into the next sections. The first section reports a short description of important aspects in Industrial domain, the research problems and current work. Next section describes the role of Semantic and artificial intelligence in industrial domain. Next section concerns the design of a prototype system for semantic search framework, in order to verify that our proposed approach is an applicable solution. Finally, we present the results of our on going work on the adaptation of the framework and we outline the future works.

II. ASPECTS TO REACH EFFICIENT SHARED KNOWLEDGE

Industrial repositories contain a large volume of digital information, generally focusing on making their knowledge resources to improve associate decision-support systems. Within a pool of heterogeneous and distributed information resources, users take site-by-site searching. Quality of search results varies greatly depending on quality of the search query from too limited set of results to a too large number of irrelevant results. For certain cases specifying a couple of keywords can be enough, if they are really specific and no ambiguity is possible [12]. Currently, electronic search is based mainly on matching keywords specified by users with sought information web pages that contain those keywords. Ambiguity of most word-combinations and phrases, which are used for searching web resources, and poor linguistic features of available web-content indexing and matching mechanisms severely affect the results of most internet searchers.

Thus, considerable effort is required in creating meaningful metadata, organizing and annotating digital documents, and making them accessible. This work concerns applications of the semantic technology for improving existing information search systems by adding semantic enabled extensions that enhance information retrieval from information systems. Use of ontologies can provides the following profits:

- Share and common understanding of the knowledge domain that can be communicated among agents and application systems.
- Explicit conceptualization that describes the semantics of the data.

In our work we analyzed the relationship between both factors ontologies and expert systems. We have proposed a method to efficiently search the target information on a digital repository network with multiple independent information sources. The use of AI and ontologies as a knowledge representation formalism offers many advantages in information retrieval. This scheme is based on the principle that knowledge items are abstracted to a characterization by metadata description, which is used for further processing. This characterization is based on a vocabulary/ontology that is shared to case the access to the relevant information sources. This motivates researchers to look for intelligent information retrieval approach and ontologies that search and/or filter information automatically based on some higher level of understanding that is required. We make an effort in this direction by investigating techniques that attempt to utilize ontologies to improve effectiveness in information retrieval.

To reach these goals we need the capacity of different information systems, applications and services to communicate, share and interchange data, information and knowledge in an effective and precise way, as well as to integrate with other systems, applications and services in order to deliver new electronic products and services.

III. SYSTEMS AND SERVICES INTEROPERABILITY REQUIREMENTS

Connectivity and interoperation among computers, among entities, and among software components can increase the flexibility and agility of industrial systems, thus reducing administrative and software costs for industry. In the business case, expands to include the ability of two or more business processes, or services, to easily or automatically work together [13]. It is clear that the ability to interoperate is key to reducing industrial integration costs and inefficiencies, increasing business agility, and enabling the adoption of new and emerging technologies. Interoperability is the ability of two or more industrial assets like hardware devices, communications devices, or software components, to easily or automatically work together.

ISO/IEC 2382 Information Technology Vocabulary defines interoperability as the capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units. An interoperability framework can be described as a set of standards and guidelines, which describe the way in which organizations have agreed, or should agree, to interact with each other.

In this context, interoperability is the ability of information and communication technology systems and of the business processes they support to exchange data and to enable sharing of information and knowledge. Technical dimension of interoperability includes uniform movement of industrial data, uniform presentation of data, uniform user controls, uniform safeguarding data security and integrity, uniform protection of industrial confidentiality, uniform assurance of a common degree of service quality, Figure 1.

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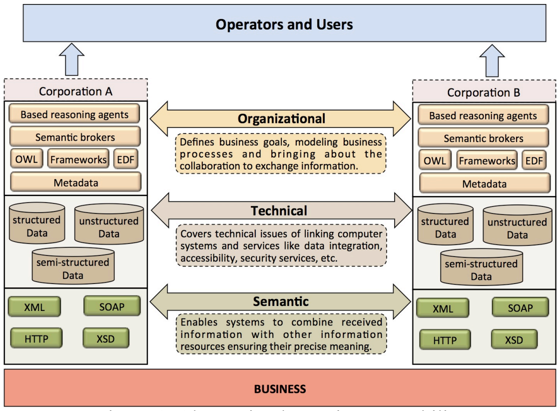

Figure 1. Abstraction layers interoperability

Specifically, the goal of semantic interoperability is to improve communication on industrial related knowledge both among humans and machines. In order to achieve this, a two-pronged approach is necessary: achieving a unified ontology and tackle concrete and clearly delineated issues. Organizational interoperability is defined as the state where the organizational components of the industrial system are able to perform seamlessly together. The vision is an integrated industrial system that provides efficient, effective and holistic. The functional goal is to allow data to be exchanged between different projects in multiple corporations using different equipment's, software etc. From multiple manufacturers or vendors. Technical interoperability consists in being able to communicate and interact between two systems coming from different manufacturers.

Different efforts are being leveraged by many standards efforts to address semantic and organizational interoperability and are proving to be a model for addressing semantic and organizational interoperability like ebXML, RosettaNet, the new UN/CEFACT work on aligning its global business process standards work with Web services, etc. In June 2002, European heads of state adopted the Europe Action Plan 2005 at the Seville summit. They calls on the European Commission to issue an agreed interoperability framework to support the delivery of European Digital services to enterprises. This recommends technical policies and specifications for joining up public administration information systems across the EU. This research is based on open standards and the use of open source software. These aspects are the pillars to support the European delivery of Digital services of the recently adopted European Interoperability Framework (EIF) [14] and its Spanish equivalent (MAP, 2014). This document is a reference for interoperability of the new Interoperable Delivery of Pan-European Digital Services to Public Administrations, Business and Citizens program (IDAbc). Member States Administrations must use the guidance provided by the EIF to supplement their national Interoperability Frameworks with a pan-European dimension and thus enable pan-European interoperability [15].

Furthermore achieving semantic and organizational interoperability requires strictly agreeing on the meaning of information and aligning business processes across enterprises/industries. At one level, general cross-industry frameworks and software infrastructure approaches can be, and are being, developed for semantics and business processes. For example, general semantics for major business transactions, such as purchase orders and invoices, are outlined through standards such as Universal Business Language (UBL), UN/CEFACT Core Components, and Open Applications Group Integration Standard (OAGIS).

IV. SYSTEM ACHITECTURE AND KEY ELEMENTS

Our system works comparing items that can be retrieved across heterogeneous repositories and capturing a semantic view of the world independent of data representation. The proposed architecture is based on our approach to share information in an efficient way by means of metadata characterizations and domain ontology inclusion. It implies to use ontology as vocabulary to define complex, multi-relational case structures to support the CBR processes [16]. The goal is achieved from a search perspective, with possible intelligent infrastructures to construct decentralized industrial repositories where no global schema exists. This goal implies the application of CBR technique.

In order to support the semantic shared knowledge in industrial repositories, a prototype CBR and ontology based techniques have been development. The architecture of our system is shown in Figure 2, which mainly includes four elements: the acquire engine, ontology, knowledge base, and graphic user interface.

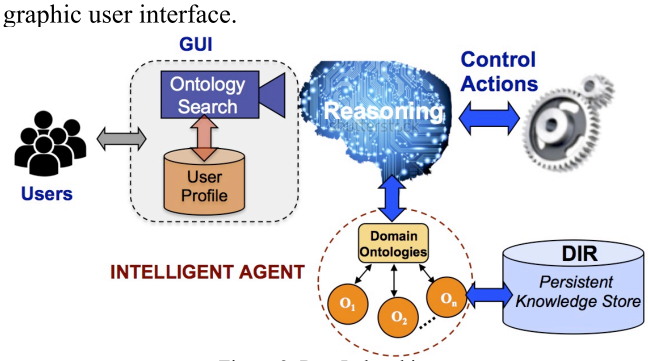

Figure 2. ReasInd architecture

A. *The Acquire Engine - Case Based Reasoning*

CBR is a problem solving archetype that solves a new problem, by remembering a previous similar situation and by reusing knowledge of that state. In CBR application, problems are described by metadata concerning desired characteristics of an industry resource, and the solution to the question is a pointer to a resource described by metadata. A new difficult is solved by retrieving one or more previously experienced cases, reusing the case, revising, and retaining. In our system when a description of the current request is input to the system the reasoning cycle may be described by the following processes [17].

The system retrieves the closest-matching cases stored in the case base. Reuse a complete design, where case-based and slot-based adaptation can be hooked, is provided. If appropriate, the validated solution is added to the case for use in future problem solving. Check out the proposed solution if necessary. Since the proposed result could be inadequate, this process can correct the first proposed solution. Retain the new solution as a part of a new case. This process enables CBR to learn and create a new solution. The solution is validated through feedback from the user or the environment, Figure 3.

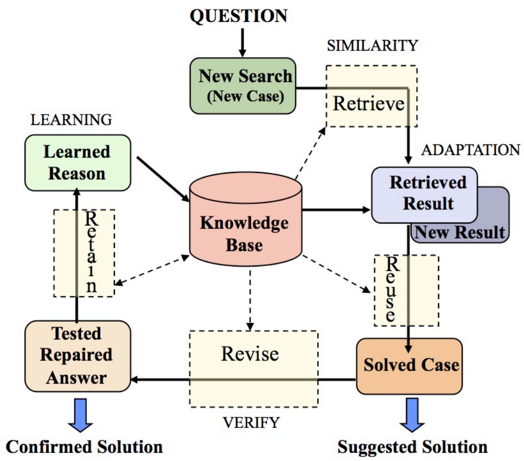

Figure 3. ReasInd Case Based Reasoning Cycle

Implementing a CBR application from scratch remains a time-consuming software engineering process and requires a lot of specific experience beyond pure programming skills. This involves a number of steps, such as: collecting case and background knowledge, modeling a suitable case representation, defining an accurate similarity measure, implementing retrieval functionality and implementing user interfaces. In this work, we have chosen framework jColibri to development the intelligent search.

JColibri is a java-based configuration that supports the development of knowledge intensive CBR applications and helps in the integration of ontology in them [18]. This way the same methods can operate over different types of information repositories. The Open Source JColibri system provides a framework for building CBR systems based on state-of-the-art software engineering techniques. JColibri is an open source framework, which affords the opportunity to connect easily an ontology in the CBR application to use it for case representation and content-based reasoning methods to assess the similarity between them. Nevertheless, at the same time, it ensures enough flexibility to enable expert users to implement advanced CBR applications.

B. *Knowledge Base.*

The understanding provided through semantic models is critical to being able to properly drive the correct insights from the monitored instrumentation, which ultimately can lead to optimizing business processes or, in this case, industry services. As a result, semantic models can greatly enhance the usefulness of the information obtained through operations integration solutions. In the physical world a control point such a valve or temperature sensor is known by its identifier in a particular control system, possibly through a tag name like 103-AA12.

CBR case data could be considered as a portion of the knowledge, i.e. metadata about resources. The metadata descriptions of the resources and objects (cases) are abstracted from the details of their physical representation and are stored in the case base. Every case contains both description problem and the associated solution. The information model provides the ability to abstract different kinds of data and provides an understanding of how the data elements relate. A key value of the semantic model then is to provide access to information in context of the real world in a consistent way.

Semantic models allow users to ask questions about what is happening in a modeled system in a more natural way. As an example, an oil production enterprise might consist of five geographic regions, with each region contains three to five drilling platforms, and each drilling platform monitored by several control systems, each having a different purpose. One of those control systems might monitor the temperature of extracted oil, while another might monitor vibration on a pump. A semantic model will allow a user to ask a question like, "What is the temperature of the oil being extracted on Platform 5?", without having to understand details such as, which specific control system monitors that information or which physical sensor is reporting the oil temperature on that platform. Within a semantic model implementation, this information is identified using "triples" of the form "subject-predicate-object"; for example:

Tank1 <has temperature> Sensor 7
Tank 1 <is part of> Platform 4
Platform 4 <is part of> Plant1

These triples, taken together, make up the ontology for Plant1 and can be stored in the model server. This information, then, can be easily traversed using the model query language more easily than the case without a semantic model to answer questions such as "What is the temperature of tank 1 on Platform 4".

C. *Ontology Development.*

Ontology models can be used to relate the physical world, to the real world, in the line-of-business and decision makers. The objective of our system is to improve the modeling of a semantic coherence for allowing the interoperability of different modules of environments dedicated to the industrial area. We have proposed to use ontology together with CBR in the acquisition of an expert knowledge in the specific domain. We need a vocabulary of concepts, resources and services for our information system described in the scenario, which requires definition about the relationships between objects of discourse and their attributes. The primary information managed in the domain is metadata about industrial resources, such as guides, digital services, alarms, information, etc. ReasInd project contains a collection of codes, visualization tools, computing resources, and data sets distributed across the grids, for which we have developed a well-defined ontology using Resource Description Framework (RDF) language [19].

The total set of entities in our semantic model comprises the taxonomy of classes we use in our model to represent the real world. Together these ideas are represented by an ontology. This provides the semantic makeup of the

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information model. The vocabulary of the semantic model provides the basis on which user-defined model queries are formed. Our ontology can be regarded as quaternion ReasInd:={caller, resources, properties, relation) where caller represent the user kinds, resources cover different information sources like electronic services, web pages, BB.DD., guides, etc. Also, properties contains all the characteristics of the services and resources and a set of relationships intended primarily for standardization across ontologies. We integrated three essential sources to the system: electronic resources, a catalogue of documents, and personal Data Base, Figure 4.

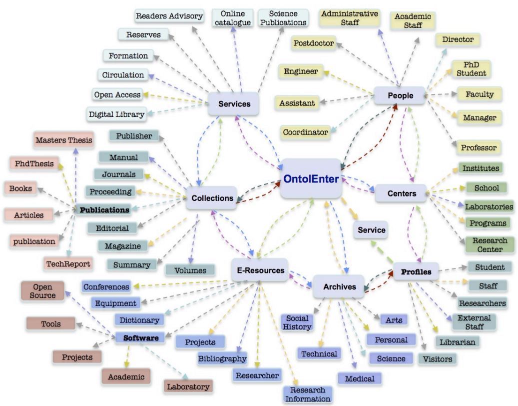

Figure 4. Class hierarchy for the ReasInd ontology

The W3C defines standards that can be used to design the ontology [20]. We wrote the description of these classes and the properties in RDF semantic markup language. We have chosen Protégé as our ontology editor, which supports knowledge acquisition and knowledge base development. Protégé provides an environment for the creation and development of underlying semantic knowledge structures-ontologies and semantically annotated web services. Protégé organizes these elements like a dynamic process workflow [21].

After designing the ontology, we wrote the classes and the properties description of in RDF semantic markup language. Then the domain expert, in this case, administrative staff fills blank units of instance according to the domain knowledge. 13.000 cases were collected for user profiles and their different resources and services. Each case contains a set of attributes concerning both metadata and knowledge.

D. *Graphic User Interface.*

ReasInd is a platform, which is an intermediate link between users and search engine. Keeping in mind that our final goal is to reformulate requests in the ontology to queries in another with least loss of semantics. We come to a process for addressing complex relations between ontologies. By using ReasInd, the user can tune the query in accordance with his needs, excluding answers from an inappropriate domain and add semantically similar results. Advanced conversational user interface interacts with the users to solve a query, defined as the set of questions selected and answered by the user during the conversation. The real way to get individualized interaction between a user and ReasInd is to present the user with a variety of options and to let the user choose what is of interest at that specific time. In our system, the user interacts with the system to fill in the gaps to retrieve the right cases, Figure 5.

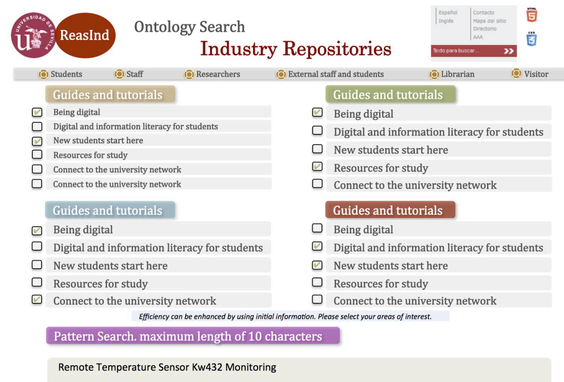

Figure 5. Graphical User interface

Transformation algorithm was implemented in the research prototype as the combined capability of the query transformation agent and the ontology agent of the intelligent multi-agent information retrieval mediator. The system has different users profiles to help to user to build a particular environment, which contains his interest search areas in the industry repositories domain: Plan Managers, Assistants, Operators, and Engineers. In this intelligence profile setting, people are surrounded by intelligent interfaces merged, thus creating a computing-capable environment with intelligent communication and processing available to the user by means of a simple, natural, and effortless human-system interaction. If the information space is designed well, then this choice is easy, and the user achieves optimal information through the use of natural intelligence, that is, the choices are easy to understand so that users know what they will see if they click a link, and what they annul by not following other links.

Profile agents assist to learners with the search, according to the specifications they made. The search parameters in a profile, the start of a search, or the access to the list of retrieved learning objects, can be controlled by invoking appropriate search operations, which extract metadata from learning resources. Ideally, profile agents learn from their experiments, communicate and cooperate with other agents, around in DIRs.

V. Experimental Evaluation

In order to validate our approach, we have developed an intelligent control architecture in an industrial domain, concretely in an electric power system. This system integrates the management knowledge into the network resources specifications. We study an example of alarm detection and intelligent troubleshooting. We have used a network which belongs to a company in the electrical sector Sevillana-Endesa's (SE) a Spanish power utility. ReasInd is used to optimize the operation of hundreds of connected sensors currently installed. The Spanish power grid company has got a network using wireless on the regional high-tension power grid. These low-cost wireless sensors and accompanying analytics can dramatically improve plant performance, increase safety, and pay for themselves within months. The use of integrating knowledge in agents can help the system administrator in using the maximum capabilities of the intelligent network management platform without having to use another specification language to customize the application.

We have used the SCADA system due to the management limitations of network communication equipment. SCADA consists of the following subsystems, Figure 6:

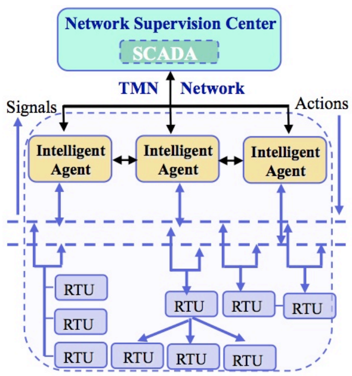

Figure 6. Elements of the prototype

- Remote Terminal Units (RTUs) connecting to sensors in the process, converting sensor signals to digital data and sending digital data to the supervisory system.
- Communication infrastructure connecting the supervisory system to the RTUs.
- A supervisory computer system, gathering acquiring data on the process and sending commands control to the process.

ReasInd monitors in real time, the network's main parameters, making use of the information supplied by the SCADA, placed on the main company building, and the RTUs are installed at different stations. SCADA systems are configured around standard base functions like data acquisition, monitoring and event processing, data storage archiving and analysis, etc. The fundamental role of an RTU is the acquisition of various types of data from the power process, the accumulation, packaging, and conversion of data in a form that can be communicated back to the master, the interpretation and outputting of commands received from the master, and the performance of local filtering, calculation and processes to allow specific functions to be performed locally. The supervision below and RTU includes all network devices and substation and feeder levels like circuit breakers, reclosers, autosectionalizers, the local automation distributed at these devices, and the communications infrastructure.

ReasInd allows the operator to search information, alarms, or digital and analogical parameters of measure, registered on each RTU. Starting from the supplied information, the operator is able to undertake actions in order to solve the failures that could appear or to send a technician to repair the stations equipment. The system has the capability of selecting an agent, which is best suited for satisfying the client's requirement, without the client being aware of the details about the agent. Collaborative agents are useful, especially when a task involves several systems on the network.

VI. EVALUATION AND CORROBORATIONS

Experiments have been carried out in order to evaluate the effectiveness of run-time ontology mapping. The main goal has been to check if the mechanism of query formulation, assisted by an agent, gives a suitable tool for augmenting the number of significant cases, extracted from DIRs, to be stored in the CBR. For our experiments, we considered 15 users with different profiles. So that we could establish a context for the users, they were asked to at least start their essay before issuing any queries to the system. They were also asked to look through all the results returned by the system before clicking on any result. In each experiment, we report the average rank of the user-clicked result for our baseline system, another search engine, and for our system ReasInd [22]. Then we calculated the rank for each retrieval document by combining the various values and comparing the total number of extracted documents and documents consulted by the user, Figure 7.

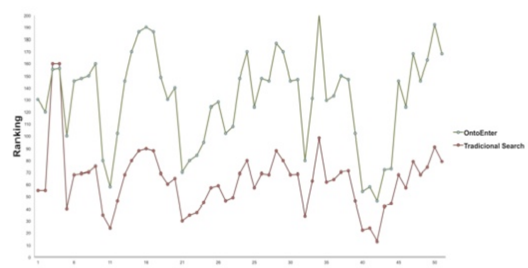

Figure 7. Performance ReasInd & traditional ES

In our study domain, we can observe that the best final ranking was obtained for our prototype and an interesting improvement over the performance of others search engines. Our system performs satisfactorily with about a 98.5 % rate of success in real cases.

During the experimentation, heuristics and measures that are commonly adopted in information retrieval have been used. Statistical analysis has been done to determine the importance values in the results. While the users were performing these searches, an application was continuing running in the background on the server, and capturing the content of queries typed and the results of the searches. We will discuss the issue of response time for five agents associated with transceiver resources. We can establish that ReasInd speed in our domain improves the answer time and the average of the traditional search engine. The results for ReasInd are 25,4 % better than executing time searches/sec in the traditional search engines.

VII. CONCLUSION AND FUTURE WORKS

Semantic models based on industry standards take that one step further, especially as application vendors adopt those standards, which, as always, will happen more rapidly through pressure from the user community. Semantic models play a key role in the evolving solution architectures that support the business goal of obtaining a complete view of "what is happening" within operations and then deriving business insights from that view. In this paper, we provide different possibilities, which semantic web opens for industry. One important objective is to study appropriate industrial cases, collect arguments, launch industrial projects and develop prototypes for the industrial companies that not only believe together with us but also benefit from the Semantic Web.

We have investigated how the semantic technologies can be used to provide additional semantics from existing resources in industry repositories. We investigated how the semantic technologies can be used to provide additional semantics from existing resources in industrial repositories. For this purpose, we presented ReasInd a system based on ontology and AI architecture for knowledge management in industrial repositories.

This study addresses the main aspects of a semantic and intelligent information retrieval system architecture trying to answer the requirements of the next-generation semantic search engine. We conclude pointing out an important aspect of the obtained integration: improving representation by incorporating more metadata from within the information and intelligent techniques into the retrieval process, the effectiveness of the knowledge retrieval is enhanced. This scheme is based on the principle of the knowledge items that are abstracted to a characterization by metadata description, which is used for further processing. We have proposed to use ontology together with CBR in the acquisition of an expert knowledge in the specific industry domain. The study analyses the implementation results and evaluates the viability of our approaches in enabling search in intelligent-based digital repositories.

Future work will be concerned with the design of distributed and self-managed industry services, which are able to automatically discover, compose, and integrate heterogeneous components, able to manage heterogeneous data/knowledge/intelligence sources, able to create, deploy and exploit linked data, and able to browse and filter information based on semantic similarity and closeness.

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