Intelligent Agents to Efficient Management Industrial Services and Resources

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***Abstract*— Increasing product and process complexity combined with rapidly changing markets and dynamic competition are daily challenges faced by industries. Current industrial platforms need to evolve in order to support different advanced capabilities including semantic interoperability, self-optimization between edge and cloud, sensor fusion and processing, and edge-aware stream processing, among others. Companies can benefit greatly from of Internet of Things as a tool for finding growth in unexpected opportunities. In this area an enormous quantity of heterogeneous and distributed information is stored in databases, web sites and digital storehouses. In the traditional search engines, the information stored in Digital Industry Repository (DIR) is treated as an ordinary database that manages the contents and positions. 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. 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. Our approach for realizing content-based search and retrieval information implies the application of the Case-Based Reasoning technology and ontologies. The objective here is thus to contribute to a better knowledge retrieval in the industrial domain. We have developed a prototype, which suggests a new form of interaction between users and digital enterprise repositories, to support efficient sharing of distributed knowledge.**

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

I. INTRODUCTION

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, and refining equipment. This data and information are stored in digital repositories, digital archives, and business Web sites. Digital Industry Repository (DIR) presents 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. A primary research goal thereby is the development of concepts for semi-automatic service composition to support flexibility in re-tooling knowledge and quick adaptation to failures in the automation chain.

Digital repositories are online databases that provide a central location to collect, contribute and share knowledge resources to use in the industrial domain. In order to remain competitive, companies must be able to develop products and services quickly and manage data and knowledge efficiently. Access to these collections poses a serious challenge. Mechanisms to retrieve information and knowledge from digital repositories have been particularly important. Artificial Intelligence (AI) and Semantic Web provide the common framework to allow knowledge to be shared and reused in an efficient way. Results generated by the current searches are a list of results that contain or treat the pattern. Although search engines have developed increasing efficiency, information overload obstructs precise searches. Thus, it is necessary to develop new intelligent and semantic models that offer more possibilities [1]. 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.

There are researchers and related field works that include intelligent techniques to share information such as [2] that 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 [3]. Huang et al. [4] propose an intelligent human-expert forum system to perform more efficient knowledge sharing using fuzzy information retrieval techniques. Yang et al. [5] 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. [6] suggest a Semantic Web technologies-based multi-agent system to allow automatically controlling 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. The architecture presented differs from other reference architectures and we include it here due to its widespread use and importance in designing Internet of Things (IoT) systems capable of handling the tremendous amounts of data and knowledge generated by the sensors. In [7], the authors propose the construction of an ontology to formalize the industrial management knowledge. Bertola et al. [8] 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 [9], the authors present an approach, which allows users to semantically query the building information modeling design paradigm using a domain vocabulary, capitalizing on building product ontology formalized from construction perspectives. Zhang et al. [10] 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 [11], the authors present a method for selecting a semantic similar measure with high similarity calculation accuracy for concepts in two different Computer-aided design model data ontologies.

In addition, the advancing development of integrated intelligent management systems has motivated to researchers to address the specific problem of integrating knowledge management. Many researchers have suggested that intelligent sensor network technologies could improve the effectiveness and efficiency of real-time management. In [12] authors have developed a distributed information management system to integrate and manipulate the heterogeneous, distributed information resources in the Iranian power industry. Mehrpoor et al. [13] describe an intelligent service to improve knowledge and information accessibility by personalizing the knowledge and information based on the stakeholder's situation in their working life, which is known as a recommender system. In [14], the authors study a grid-based infrastructure, which adopts the semantic Web and the Grid to share information in the press industry chain. Chen et al. [15] address the important issues in developing domain-specific ontology for manufacturing used in Industrie 4.0 demonstration production lines. For this purpose a generic ontology is developed considering all the aspects about the product from customized order to resulting production.

There is a lot of research on applying AI and semantic techniques to share knowledge. In this work we focus upon the latter tasks, which are intended to guarantee the desired quality of network services to the industry and to collect and evaluate the associated knowledge. Information has to be gathered for the purposes of accounting and for gaining information for future industrial services design. In this paper, we present a full integration of AI technologies and semantic methods during the whole life cycle from the industrial point of view. Our work differs from related projects in that we build ontology-based contextual profiles and we introduce to an approach using metadata-based ontology search and expert system technologies [16]. More specifically, the main objective of this research is to search possible intelligent infrastructures based on the construction of 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 to environments in the industrial domain and incorporates Semantic Web and AI technologies to enable precise location of industrial resources.

The remaining paper is organized as follows: In Section II reports a short description of important aspects in Industrial domain, the research problems and current work. Section III describes the systems and services interoperability requirements. Section IV studies the role of semantic and artificial intelligence in industrial domain. Section V y Section VI concern the design of a prototype system for semantic search framework, in order to verify that our proposed approach is an applicable solution. Section VII and Section VIII demonstrate the proposed intelligent architecture can successfully control an industrial domain. Finally, Section IX concludes chapter and outlines the future work.

II. TRANSFORMING INDUSTRIAL VALUE CREATION

Industrie 4.0 is currently one of the most frequently discussed topics by researches. Its aim deals with intentions between science and industry with continuous improvements of the general conditions for innovations. Industrie 4.0 is a strategic initiative to take up a pioneering role in industrial Information Technology (IT), which is currently revolutionizing the manufacturing engineering sector. Industrie 4.0 covers science and technology-based solutions in different specific fields like climate and energy, health and nutrition, mobility, security, and communication. Industrie 4.0 represents the coming fourth industrial revolution, which connects embedded system production technologies and smart production process to pave the way to a new technological age. In other words, industrial production machinery no longer simply processes the product, but the product communicates with the machinery to tell it exactly what to do. In more depth, we recognize six design principles of Industrie 4.0:

- Interoperability: it means that it is crucial to set up standards in order to rule the communication between Cyber-Physical Systems (CPS) of various manufacturers.
- Virtualization: necessary for an overall monitoring of physical processes, thus enables us to use it for simulations of models.
- Decentralization: it enables the different systems to make their decisions separately.
- Real-time capability: collecting of data in each step of the process should be in real-time.
- Service orientation: reliable service must be considered as well.
- Modularity: Modularity brings up flexibility to in terms that each individual model must be designed in such a way that it is easy to replace or apply new innovations.

In the age of Industrie 4.0, products have barcodes or Radio Frequency Identification (RFID) chips on the surface to pass information to machines, which communicate with and control each other. The physical and virtual worlds merge into cyber-physical systems. Not only intelligent machines and products, but also all entities involved in production, including suppliers and customers along the entire value chain are networked with Information Communications Technology (ICT), from logistics to production and marketing to service. They may have a need to know any information to provide efficient services: What product belongs in which packaging? What transport container is where? What processing step comes next? What machine requires maintenance or replacement parts, and when? Where can unrealized cost reduction potential be found in the logistics process?

The reason why researches have been investing so much effort in this project is that technology is the main building block for innovations and innovations shape the future. An important aspect is the connection between the physical and the knowledge of resource management and this connection can be established due to DIRs. DIRs contain data and knowledge of management about physical resources, which conform IoT. Embedded computer and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa. This demonstrates why efficient knowledge retrieval is important to monitor physical processes, to create a virtual copy of the physical world and then make decentralized decisions.

For example, a machine at step 3 of a production process could alert other machines from steps 4 and onward that the production will be delayed a bit because there's an urgent fix that needs to be done on the machine at step 3. Of course, there will still be humans interacting with the machines in this manufacturing process. A production plant manager will still manage the plant, but s/he will have more data coming from all the machines, therefore enabling a better use of resources, better scheduling of maintenance and delays. Based on current technology, the manager located in the middle of the plant, with a tablet in hand, looking at all the data coming in from the machines, taking in all the information coming in verbally from the employees, and making decisions based on this data can therefore be: adjusting the production schedule, ordering supplies and adjusting employee assignments all according to the current plant conditions.

The knowledge and information data volumes produced in this complex system are permanently available and evaluated in real time. Not only do employees have mobile access to this data, they can also intervene in the processes using mobile devices. In this sense, the efficient knowledge retrieval is becoming increasingly important. The benefits for participants along the entire value chain are varied. Waste is reduced, the ability to respond to individual customer wishes is improved, and the production of one-offs, and very small quantities becomes more cost-effective. Faster, more reliable decisions can be made, business processes become more flexible and dynamic, new business models are created. Downstream services complement the traditional portfolio of manufacturing companies.

To reach these goals we need the capacity of different information systems, applications and services to retrieve, communicate, share and interchange knowledge in an effective and precise way, as well as to integrate with other systems, applications and services in order to deliver new 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. This capacity expands the industrial processes to automatically work together in an eficency way [17]. 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).

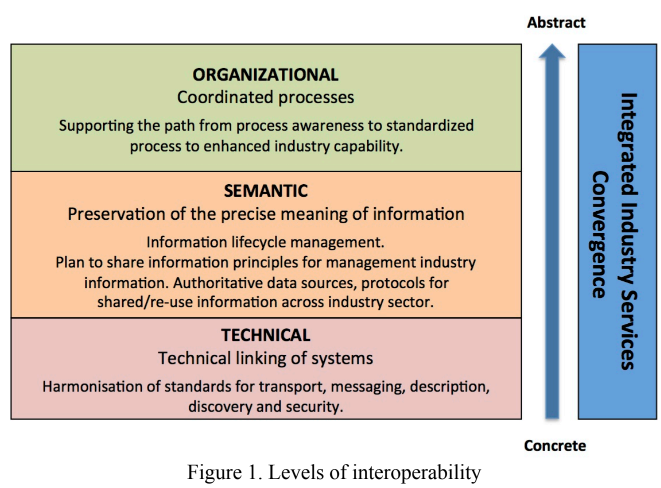

Figure 1. Levels of interoperability

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

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).

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 and other services. In June 2002, European heads of state adopted the Europe Action Plan 2005 at the Seville summit. They call 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 European Union. 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) [18] and its Spanish equivalent [19]. 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 [20].

IV. Implementation of Industrie 4.0 with Ontologies and Artifical Intelligence

In the current industry it is a need to disperse real time data, which can spread the effort and resources more accurately. So, productivity is increased and the use of raw material is optimized. The quality of the final product should also be improved; if the data coming from design process shows that the real value used always has an offset from the set point, then the design plans can be adjusted accordingly and the simulations as well. This will enable a simulation that actually corresponds to reality, and eventually a product that is closer to its original design. Adaptability is a big plus in Industrie 4.0. So, intelligent management of huge amounts of resources and associated data are areas that need a rapid development.

In practice, it is apparent that some companies have only a rudimentary grasp on Industrie 4.0 and so a basic automation and IT infrastructure must first be created. Even more advanced companies generally have a conventional system environment according to the classic automation pyramid with relatively rigid and outmoded systems that were installed for a specific task. These systems are usually based on proprietary and therefore inflexible data structures. Consequently, modifications and expansions are very time consuming and costly. This makes it possible to achieve enormous cost savings and economies of scale. Management has genuine real-time information for its decision-making processes. The results of any action taken can be directly measured, identified and then corrected as needed.

The Industrie 4.0 vision assumes the secure communication and cooperation of all participants across companies in real time for the entire lifetime of the product. The first step towards Industrie 4.0 for most companies is the complete vertical integration and digitization of the systems involved in the manufacturing process via a Manufacturing Execution System (MES), which allows real-time transparency. A horizontal integration of individual functionalities is also necessary. In this context, MES, the information hub, is the central element that collects, analyzes, processes and provides the other systems with the big data. The information that Industrie 4.0 provides together with, for example, big data, social media, and cloud computing, make it possible to optimize the decision-making process, secure design decisions early on and respond flexibly to disturbances, as well as optimize all the resources across more than one site.

In the industry domain levels of service provision can be influenced by different operations and parameters that affect the bottom-line results:

- Do you need to know in real time the status of many different components and devices in a large complex system?
- Do you need to measure how changing inputs affect the output of your operations?
- What gear must you to control, in real time, from a distance?
- Where are you lacking accurate, real-time data about key processes that affect your operations?

This has a variety of benefits along the entire value chain. It improves the ability to respond to individualized customer needs and makes it more profitable to manufacture individual units and small quantities. The flexibility is progressing through the dynamic design of business processes via the Internet in various dimensions as well as agile engineering processes. Intelligent monitoring and control increases efficiency and maximizes profitability. Here are few of the things you can do with the information and control capabilities you get from an intelligent system:

- Detect and correct problems as soon as they begin.
- Measure trends over time.
- Discover and eliminate bottlenecks and inefficiencies

• Control larger and more complex processes with a less specialized staff.

Industrie 4.0 is actually a concept, which has the strength of focusing the development efforts in the right places. Once the concept is defined, we can see where the system fails to perform, and this is where the effort for improvement can be concentrated. Using a simple analogy, we can compare the industrial paradigm with Formula One racing where the cars are going around a track with thousands of sensors monitoring the cars. Every time a car goes past the pit wall, the systems downloads data, and the race engineers tell the driver how to drive in response to that data. That is what is needed in our factories. There needs to be the equivalent of the pit wall somewhere to make sure that the factory machinery is working better than that of the competitors.

We propose a modern factory with all the steps automated and interrelated, with operators on their tablets tracking on going production. In industry it is important to stay aware of the global strategies of Industrie 4.0, and think of Industrie 4.0 when you acquire new equipment; a sensor with an Ethernet connection will eventually be useful to connect to the rest of the factory.

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.

Industrial repositories contain a large volume of digital information, generally focusing on making their knowledge 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. 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.

Essentially, most Industrie 4.0 experts agree that a number of norms and standards already exist. Use of ontologies can provides the following benefits:

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

In our work we analyzed the relationship between both thecniques 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 an ontology that allows sharing the relevant information domains 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 what is required. We make an effort in this direction by investigating techniques that attempt to utilize ontologies to improve effectiveness in information retrieval.

V. Implementation Intelligent Agents

Nowadays there are many platforms and tools available for the retrieval information and data. Although these tools are powerful in locating matching terms and phrases, they are considered passive systems. Intelligent Agents (IAs) may prove to be the needed instrument in transforming these passive search and retrieval systems into active, personal user assistants. In this sense, IAs are currently used to improve the search and knowledge retrieval from online databases and repositories. Software agents function in a particular environment, i.e., an agent platform, which is often populated by other agents and processes. While there are obvious similarities, there are also significant differences between agents and objects. The first is in the degree to which agents and objects are autonomous.

A model uses multiple agents, which deliver personalized search engine results. An IA is a data-processing entity, which carries out in an autonomous way tasks delegated by a user, but also a part of software, which can operate on behalf of another entity. In our context, intelligent software agents may be provided with a user-friendly interface, which is used to acquire user specifications of industry domain. In the context of this research, however, the tasks that we are primarily concerned with include reading, filtering and sorting, and maintaining information.

In the industry environment, IAs can be used to recommend actions, or distribute searches of the users among available multi-agents. The IA platform hosts several IAs, each of them having local knowledge and which may move autonomously in form of mobile intelligence to other agent platforms. An intelligent software agent has characteristics like mobility, ability to interact and to cooperate, learn and even reason, based on certain knowledge representations. These skills can be used for personalization or information filtering, motivating the usage of intelligent software agents in the context of educational systems to improve the knowledge retrieval. Each IA contains a list of knowledge storage registries to find additional content, and a list of other known IA platforms, which may belong to other institution. IAs can update their lists by communicating with other agents using a predefined communication protocol.

The agent knowledge acquisition can happen through experience problem solving, and inductive/deductive reasoning. In our proposal the IA intelligence consists of two components: semantic intelligence and rational intelligence. These two parts have different purpose and characteristics (Figure 2).

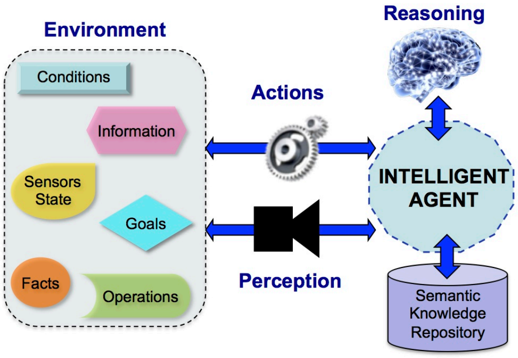

Figure 2. Intelligent Agent components

Rational intelligence depends on insight, which is the ability to detect, establish, forecast, and modulate relationships between problems and solutions. A high rational intelligence degree is usually not enough to produce proper behaviors and efficient results in the search engine. An engine with a high rational intelligence also needs to have a high semantic intelligence to thrive. Semantic intelligence improves productivity and effectiveness in making meaning connections. Semantic intelligence links knowledge through conceptual constructs (ontologies) connecting pieces of knowledge critical to achieve the integration of the data meaning. Thus, semantic reflects the knowledge in a general work domain, but rational intelligence decides how wisely these abilities are engaged, directed, and applied.

A. Ontology Development

Interoperability is the ability of two or more systems or components to exchange data and uses of information. Semantic interoperability is achieved when the interacting system attributes the same meaning to an exchanged piece of data, ensuring consistency of the data across systems regardless of individual data format. The semantics can be explicitly defined using a shared vocabulary as specified in an ontology. Semantic interoperability can be applied to all parts of an IoT system, i.e., on IoT platforms in the cloud, but also reaching to edge components and IoT devices. An important area to study IAs communication, collaborative, problem solving, and interaction in industry environments are the IA. These objects must have work area knowledge to solve domain-specific problems. In industry domain semantic interpretation of the information plays an important role in knowledge communication and transferring between the plant sensors and the control center. Considering the similarities and divergences in the different knowledge representation kinds we have chosen ontology. Ontology is a formal and explicit specification of shared conceptualization of a domain of interest. IAs must have common shareable ontology to share knowledge with each other and this common sharable ontology must be represented in a standard format so that all software agents can understand and thus communicate with.

Ontology is the knowledge structure, which identifies the concepts, property of concept, resources, and relationships among them to enable share and reuse of knowledge that are needed to acquire knowledge in the specific search domain. The ontology index comprises a plurality of relationships between the plurality of terms and sub-category terms of the ontology and a plurality of documents residing on the network. One or more search results that describe the one or more documents are presented to the user. The one or more documents contain the one or more search terms, or one of plurality of sub-category terms of the one or more search terms. The search request comprises one or more search terms of ontology. The ontology includes a plurality of terms.

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 Case-Based Reasoning (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, and information. 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 [21] (Figure 3).

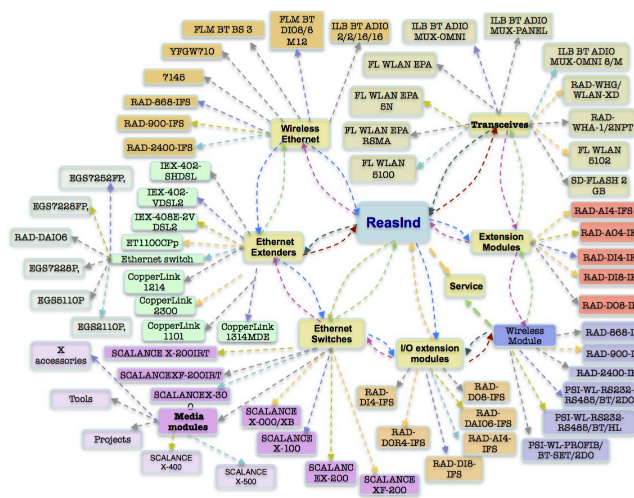

Figure 3. Class hierarchy for the ReasInd ontology

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 ontology. This provides the semantic makeup of the 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 represents the user kinds, resources cover different information sources like electronic services, web pages, databases, and guides. Also, properties contain 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 database.

We choose Protégé as our ontology editor, which supports knowledge acquisition and knowledge base development. It is a powerful development and knowledge-modeling tool with an open architecture [22]. Protégé uses OWL and RDF as ontology language to establish semantic relations [23]. For the construction of the ontology of our system, firstly we determine the domain and scope of the ontology: electronic services, web pages, DD.BB, and guides. Also it is also necessary to adapt the ontology to the user kinds needs. Second, we enumerate important terms in the ontology. It is useful to write down a list of all terms we would like either to make statements about or to explain to a user. Then we define the classes and the class hierarchy. Based on RDF Schema we describe the relations between classes, currently implemented 10 classes and about 175 properties. The ontology and its sub-classes are established according to the taxonomies profile. As mentioned in previous sections, relations among ontologies can be composed as a form of declarative rules, which can be further handled in inference engines.

The last step is to provide a conversational CBR system to retrieve the requested metadata satisfying a user query. We need to add enough initial instances and item instances to the knowledge base. Thirteen thousand cases were collected for user profiles and their different resources and services. This is sufficient for our proof-of-concept demonstration, but would not be sufficiently efficient to access large resource sets. Each case contains a set of attributes concerning both metadata and knowledge. However, our prototype is currently being extended to enable efficient retrieval directly from a database, which will enable its use for large-scale sets of resources.

VI. System Achitecture and Key Elements

The proposed architecture is based on our approach to share information in an efficient way by means of metadata characterizations and domain ontology inclusion. The system works by comparing items that can be retrieved across heterogeneous repositories and capturing a semantic view of the world independent of data representation. It implies to use ontology as vocabulary to define complex, multi-relational case structures to support the CBR processes [24]. 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 4, which mainly includes four elements: the acquire engine, ontology, knowledge base, and graphical user interface.

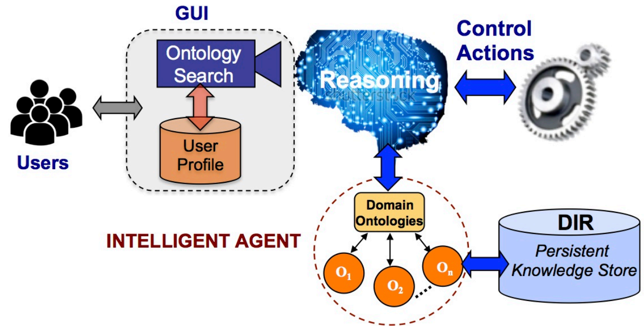

Figure 4. ReasInd architecture

A. The Acquire Engine - Case Based Reasoning

Our architecture itself is separated into three layers: DD.BB capable of storing, managing and controlling the extensive sets of knowledge; the CBR layer for indexing the knowledge for efficient retrieval and retain knowledge set; and GUI to provide low-latency functionality and access to recent data. CBR is a problem-solving architecture that solves a new problem, by remembering a previous similar situation and by reusing knowledge of that state. In the 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 difficulty is solved by retrieving one or more previously experienced cases, reusing the case, revising, and retaining. When a user introduces a description request to the system the reasoning cycle may be described by following processes (Figure 5).

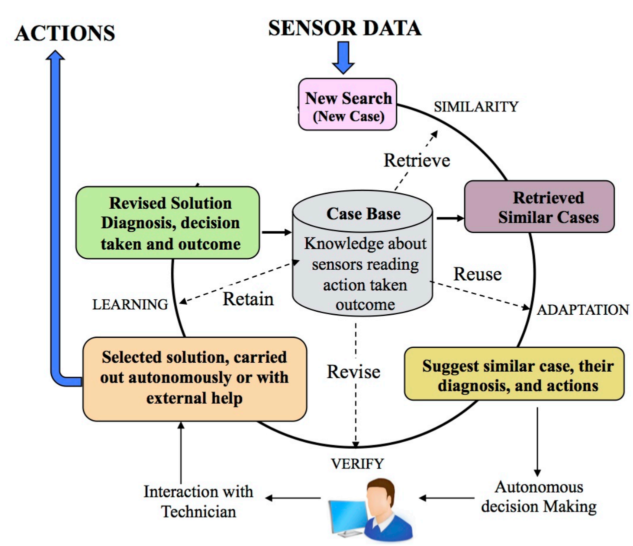

Figure 5. ReasInd Case Based Reasoning Cycle

The system retrieves the closest-matching cases stored in the case base. It reuses 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. It then checks out the proposed solution if necessary. Since the proposed result could be inadequate, this process can correct the first proposed solution. The system retains 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.

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 develop 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 [25]. 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 by 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. *Knowledgebase*

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 a description of the 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 containing 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. *Evaluating a Set of Maching Cases*

The inference engine contains the CBR component that automatically searches for similar queries-answer pairs based on the knowledge that the system extracted from the questions text. The retrieval process identifies the features of the case with the most similar query. It treats the RDF query schema and the RDF query instance as a tree then tries to match all possible interpreting paths of a query instance with annotated pictures and finally ranks the similarity match and finds the best answer. Based on the proposed representation model, we have developed a retrieval scheme for the intelligent retrieval system. Given a new case and a large precedents database, we develop the following scheme to identify those relevant precedents step by step. When a new case arises, users always want to find the factually relevant precedents that are similar in all or most representation elements. However, it is impossible to find an identical precedent with the new case due to the factual diversity of actual cases. In that case, those precedents sharing one or more representation elements with the new case are desired as they are potentially useful for making legal arguments [26].

The use of structured representations of cases requires approaches for similarity assessment that allows a comparison of two differently structured objects, in particular, objects belonging to different object classes. Retrieval strategy used in our system is cosine approach. Cosine similarity is a measure of similarity between two vectors by measuring the cosine of the angle between them [27]. The system relies on cosine similarity distance metrics when computing distance between symbolic vectors representing the retrieved cases. First, let us take an instance and break it down into features, in the simple case features can be just important attributes. Then we count the times a particular word appears in the document. What we end up with is a term vector or vector of terms and frequencies:

$$a_j = (a_{1,j}, a_{2,j}, \ldots, a_{t,j})$$
$$x = (x_1, x_2, \ldots, x_t)$$

$$similarity = Cos(\theta) = \frac{a_j \cdot x}{\|a_j\| \|x\|} = \frac{\sum_{i=1}^{n} a_{ij} \cdot x_i}{\sqrt{\sum_{i=1}^{n} (a_i)^2} \cdot \sqrt{\sum_{i=1}^{n} (x_i)^2}}$$

The attributes are used as a vector to find the normalized dot product of the two cases. By determining the cosine similarity, the system is effectively to find cosine of the angle between the two objects (Figure 6).

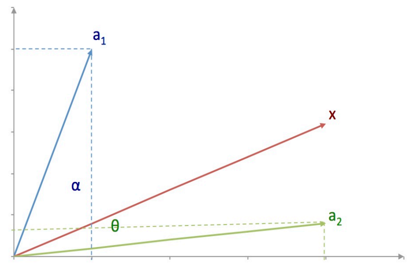

Figure 6. Similarity between documents

We can use the cosine similarity between the query vector and a document vector as a measure of the score of the document for that query. The resulting scores can then be used to select the top-scoring documents for a query. The result of cosine function is equal to 1 when the angle is 0, and it is less than 1 when the angle is of any other value. Calculating the cosine of the angle between two vectors thus determines whether two vectors are pointing in roughly the same direction. For cosine similarities resulting in a value of 0, the documents do not share any attributes because the angle between the objects is 90 degrees.

D. *graphical 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 7).

A 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.

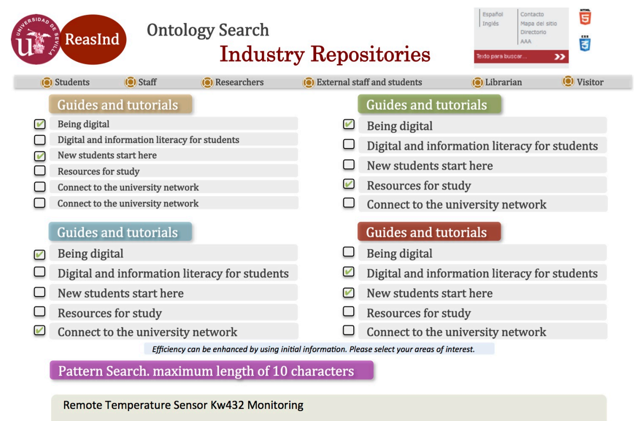

Figure 7. Graphical User interface

Profile agents assist the technicians 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 knowledge can be controlled by invoking appropriate search operations, which extract metadata from plants resources. Ideally, profile agents learn from their experiments, communicate and cooperate with other agents, around in DIRs.

VII. EXPERIMENTAL EVALUATION

As the private networks have grown from small networks into a large global infrastructure, the need to manage the huge number of hardware and software components within these networks more systematically has grown more important as well. In order to validate our approach, we have developed an intelligent control architecture in an industrial domain, specifically 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 that 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 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. To most companies, communications spending is an obscure recurring cost composed of complex bills, vendors, and services that can represent as much as 4% of their total revenue [28]. If we add to this an environment of ever-changing technology and typical business requirements such as mergers, multiple sites, and different geographic locations, the end result is a highly technical function with financial impacts that can easily be misunderstood and over-invested. It is necessary to analyze the entire telecommunications environment for an efficient management of the network resources.

We have used the Supervisory Control And Data Acquisition (SCADA) system due to the management limitations of network communication equipment (Figure 8).

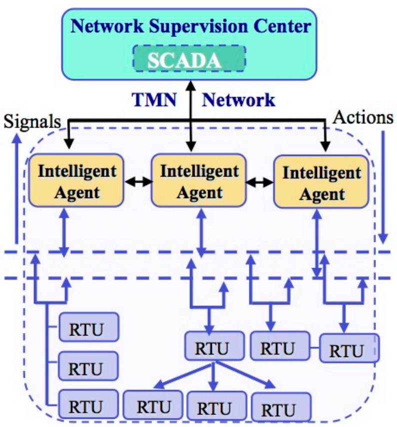

Figure 8. Elements of the prototype

SCADA consists of the following subsystems:

- 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, 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 that 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. 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 include 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 equipment of the station. 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.

VIII. 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 100 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 [29]. 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 9).

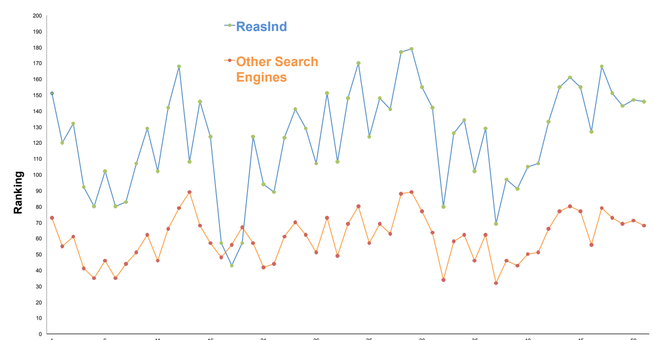

Figure 9. Performance ReasInd & traditional ES

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 important values in the results. While the users were performing these searches, an application was continuing to run 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 our prototype improves the answer time and the average of the traditional search engine. The results for ReasInd are

25.4 % better than the time to execute searches in the traditional search engines.

IX. Conclusion and Future Works

Semantic models based on industry standards take that one step further, especially in intelligent techniques application. 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 believe in the benefits of the Semantic Web.

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

We conclude by 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 enhances the effectiveness of the knowledge retrieval.

Industrie 4.0 will play a crucial role in shaping the future in the next five to ten years in the world. Various strategy and working groups are working on the Industrie 4.0 extension of existing norms and standards. 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 knowledge and 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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