

# An Intelligent Methodology for Modeling Semantic Knowledge in Industrial Networks

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*Abstract:* Networks has been involved in Industrial and IoT Applications for decades, creating new opportunities for more personalized services, improved security, greater automation and operational efficiency. Industry and businesses who prioritize and modernize their analytics strategy and technology to monetize their data will lead and succeed in our data-driven world. The network now provides even more detailed information through units and equipment databases, which provide details about the installed equipment, including models, designed capacity, performance and start / stop dates of the switches, routers, etc. repositories, digital files and business websites. Access to these collections is a serious challenge. Artificial intelligence and the Semantic Web provide a common framework for sharing and reusing knowledge in an efficient way. This article explores the architecture of intelligent agents to make the argument of an intelligent solution as opposed to traditional methods. We propose a new paradigm in which the intelligent management of the network is integrated into the conceptual repository of management information. This study focuses on an intelligent framework and language to formalize knowledge management descriptions and combine them with the existing SNMP management model. Based on the present proposal and the Internet management model, we describe the design and implementation of an integrated intelligent management platform called OntoNetwork.

*Key-Words:* - SNMP, Intelligent Agents, Ontology, Semantic Knowledge, Network Management, Digital Repositories, Expert systems, Interoperability.

## 1 Introduction

Existing communications networks support a large demand for services for which the traditional network management model is inadequate. Due to the increasing complexity and heterogeneity of networks and services, many efforts have been made to develop intelligent management techniques. The management of the resulting networks becomes more important and critical over time. Classic management architectures are not suitable for low bandwidth or offline operation. Traditional management frameworks such as SNMP and OSI are centralized approaches, in which the manager uses distributed agents to collect management information.

This approach has drawbacks, particularly due to the lack of extensibility and scalability of the model in very large networks. This restriction results from the inability of a centralized manager to handle large amounts of management information across geographically distributed sites is infallible and costly. Intelligent network management is a key technology for operating large, heterogeneous data transmission networks.

Several authors have addressed these problems over the past few years [1] [2] [3] [4] [5] [6] [7], resulting in ad-hoc and partial solutions normally based on distributed management and intelligent delegation. There is no complete Intelligent Agent (IA) integration scale applied to SNMP network management architectures.

The scope of this paper covers why IA's are well suited to meet network management requirements and how a system based on intelligent agents can be applied to achieve intelligent management of the network. The study addresses the problems that traditional network management poses and makes the AI based argument in relation to these problem areas.

We propose a comprehensive approach to discover information objects in large digital repositories based on the analysis of registered semantic metadata and the application of the Case-Based Reasoning technique. This study is based on theory, experimentation and the findings of the SNMP management model and the knowledge of the integration management to obtain an efficient network control [8]. The goal is to improve

understanding and insight of network management, and present an alternative model of distributed management network. This article presents an architecture proposal that integrates semantic specifications of management objects and knowledge of expert systems. The present work, presents an architecture in which a main semantic manager can delegate the intelligent control over several distributed AIs, improving the scalability through the distribution and allowing actions of intelligent management.

Section II examines the models of management networks, including concepts and main approaches. Section III presents the capabilities needed for efficient network management and the current shortcomings of the SNMP model. From there, section IV gives the formulation of the proposal and an outline of the various stages in the development of the system. Section V presents a high-level conceptual intelligent agent called OntoNetwork and summarizes research performance. We have tested our system on real data for fault diagnosis in a university wireless network. The results of a validation and show a significant improvement with respect to the number of rules and the error rate in other systems. Finally, we outline the conclusion and future works.

## 2 Traditional networks management models

Nowadays, there are several organizations that have developed services, protocols, and architectures for network management. The most important organizations are ISO, was the first to initiate as part of its Open Systems Interconnection (OSI) program, the development of the architecture for network management Telecommunication Management Network (TMN) developed by the International Telecommunication Union ITU), and the Internet Model by the Internet Engineering Working Group (IEFT) [9].

According to the International Organization for Standardization (ISO), the network management model defines a conceptual architecture for managing all communication entities within a network. A main concept in management networks is the managed object, which is an abstract view of a logical or physical resource to be managed in the network. Managed objects provide the necessary operations for the administration, monitoring, and control of the telecommunications network. These operations are performed using the Common Management Information Protocol (CMIP) with the

OSI model and Simple Network Management Protocol (SNMP) in the Internet model. SNMP is one of the widely accepted protocols for managing and monitoring network elements. SNMP was designed to be an application-level protocol that is a part of the Transmission Control Protocol/Internet Protocol (TCP/IP) suite [10].

The SNMP framework is based on the principle of minimally simple agents and complex administrators. The managed element provides an abstract view of an actual resource. The agent provides a management view of its underlying logical and physical resources, such as transport connections and power supplies, to management applications. For a specific management association, the management processes involved and will assume one of two possible roles, Fig. 1.

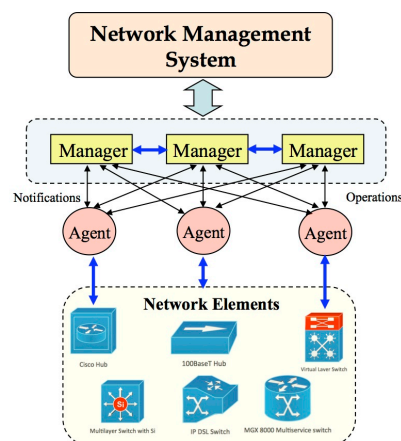


Fig. 1. Manager role and agent roll.

A manager is defined as part of a distributed network management application process [11], which is responsible for network management processes. An agent performs management operations on managed objects at the request of the manager and reports on events that have occurred in association with managed objects.

### 2.1 Information management repository

The MIB is an ASCII text file that describes SNMP network elements as a list of data objects. It is like an SNMP language dictionary, in which each object referred to in an SNMP message must appear in the MIB. SNMP objects represent unique atomic data elements that can be read or written to perform the operation of the associated resource. This set of classes of managed objects and instances under the control of an agent is known as its Management Information Base (MIB), an abstraction of network resources, properties, and states for the purpose of administration [12]. The principles of SNMP information modeling are collectively referred to as

the Management Information Structure (SMI) and are specified in [RFC1155] for SNMPv1 and in [RFC1902] for SNMPv2. The MIB is written in abstract syntax 1 (ASN.1) a standard syntax for data types and values, which is maintained by ISO.

The MIB is organized into a tree structure with individual variables, such as the state of the point or description, which is represented as leaves in the branches. The first step towards developing an agent is to define its MIB. The steps involved in the development of the MIB file are:

- Identification of data: Identify the data or objects that need to be handled using AI and expose them in the form of scalar or tabular objects. Here all knowledge associated with a specific managed resource is categorized.

- Data Definition: Construct the ASN.1 MIB definitions for IA. This study defines the different types of ASN.1 knowledge related to network resources. For this, we have used an editing tool. Editors can help in easy MIB design by hiding unimportant details from MIB syntax rules, clauses, etc. MIB editors often have an easy-to-use wizard interface through which various constructs that conform to SMIV1 specifications and SMIV2 and ASN.1 rules can be created [13].

The manager and the agent use the MIB and a relatively small set of commands to exchange information. When an SNMP device sends a trap or other message, it identifies each data object in the message with a string of numbers called Object Identifier (OID). An SNMP administrator knows the value of an object/feature, such as the status of an alarm point, the system name, or the activity time element, it will assemble a GET packet that includes the OID for each object/characteristic of interest.

### 3 Intelligent agent overview

IA are the administrative systems, they have the task of supervising or managing a group of hosts or devices in a network. Each AI executes, at all times, a software component that reports management actions through SNMP to managed objects. IA is based on management knowledge. To improve the quality of the AI description and the resulting implementations, a formal method for specifying knowledge is desirable. Formal knowledge descriptions facilitate an engineer to understand the complete information model and derive a valid, consistent and compatible implementation from it.. IA has the ability to distribute intelligence across the network and dynamically perform intelligent management functions [14]. This provides efficiency and flexibility and reduces bandwidth

constriction and overload in a single central control center. An important goal is convergence in solutions despite incomplete or inconsistent knowledge or data.

IAs can actively and dynamically seek to cooperate to solve problems using task and domain-level protocols. IAs learn the normal behavior of each measurement variable and combine intelligent knowledge to manage network resources. IA is based on three essential properties: the autonomy or independence of self-government, the communication as the ability to talk with a partner, and cooperative agents to collaborate when they can work together.

An IA is essentially a standalone software program module that is programmed to perform certain actions on behalf of a human user or other software entity in a given software environment [15]. IA can perform such actions collects management information about its local environment, stores and retrieves management information as defined in the MIB, execution of specified tasks or collaboration with other agents. These actions are carried out in an autonomous manner that requires little or no human intervention, Fig. 2.

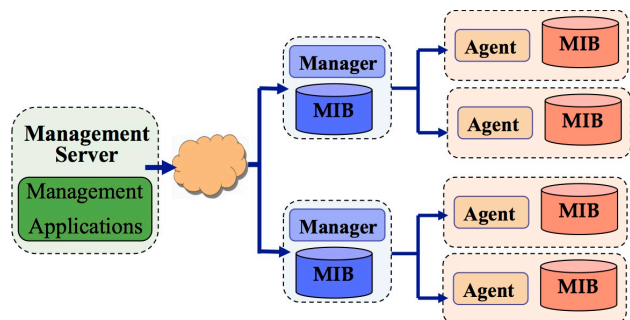


Fig. 2. SNMP intelligent agents.

Each SNMP IA maintains an information database that describes the parameters of the managed device and a knowledge base that stores all relevant information used for management purposes: data, rules, cases and relationships. If supplied with the correct MIB file, an SNMP administrator can correctly interpret the alarm data of any device that supports SNMP and perform corresponding management actions [16]. In this work, knowledge management was modeled using a semantic representation, which defines the formal specification of the types of managed objects and associated access mechanisms.

### 4 System architecture and key elements

In order to support semantic shared knowledge in industrial repositories, a prototype of CBR and techniques based on ontology have been developed. The system works by comparing items that can be retrieved through heterogeneous repositories and capturing a semantic view of the independent world of data representation. It involves using ontology as a vocabulary to define complex multi-relational case structures to support CBR processes [17]. The objective is pursued from a search perspective, with possible intelligent infrastructures to build decentralized industrial repositories where there is no global scheme. This objective involves the application of the CBR technique. The proposed architecture is based on our approach to efficiently share information through the characterization of metadata and the inclusion of domain ontologies, Fig. 3.

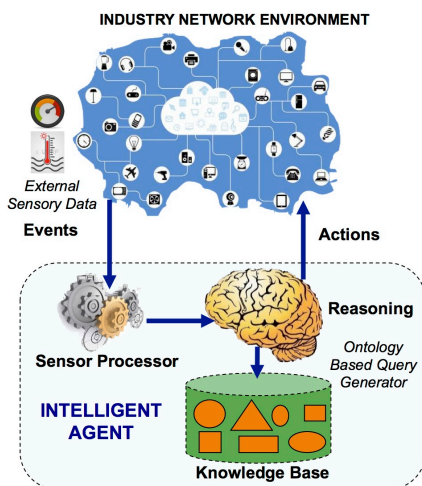


Fig. 3. OntoNetwork Architecture

The architecture of our system mainly includes four elements: the acquisition engine, the ontology, the knowledge base and the graphical user interface.

#### 4.1 The acquire engine-case Based reasoning

CBR is an archetype of problem solving that resolves a new problem recalling a similar previous situation and reusing the knowledge of that state. Implementing a CBR application from scratch remains a time-consuming software engineering process and requires a lot of specific experience beyond pure programming skills [18]. This involves a series of steps, such as case collection and background knowledge, modeling of an appropriate case representation, definition of a precise similarity measure, implementation of the retrieval functionality, and implementation of user interfaces.

In this paper, we have chosen the jColibri framework to develop intelligent search.

In the CBR application, problems are described by metadata relative to the desired characteristics of an industry resource, and the solution to the question is a pointer to a resource described by the metadata. A new difficulty is solved by recovering one or more previously experienced cases, reusing the case, reviewing, and retaining it like a new case [19]. The reasoning cycle is composed of four elementary stages. First, the system retrieves the closest match cases stored in the case base. Second, reuse a full design where case-based and slot-based adaptation can be hooked, provided. Third, if appropriate the validated solution is added to the case for use in solving future problems. Finally, check the proposed solution if necessary. Since the proposed result may be inadequate, this process can correct the first proposed solution. Keep the new solution as part of a new case. This process allows CBR to learn and create a new solution. The solution is validated through feedback from the user or the environment, Fig. 4.

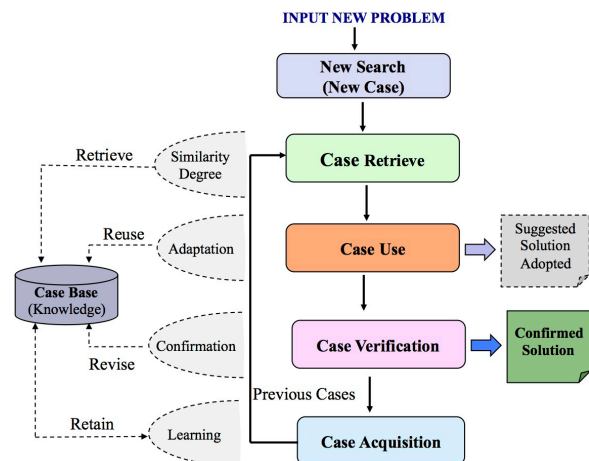


Fig. 4. OntoNetwork Case-Based Reasoning Cycle

JColibri is a java-based configuration that supports the development of CBR-intensive applications in knowledge and helps in integrating the ontology into them. Metadata descriptions of resources and objects (cases) are extracted from the details of their physical representation and stored in the case base. In this way, the same methods can operate on different types of information repositories [20]. Mapping between the two layers is done by connectors. These connectors read the columns values, and the ontology database, and return these to the application. Thus, assign these values to different attributes of the case. Based on the same idea, the case base implements a common interface for similarity methods to evaluate cases. This includes the generation of case representations, the



definition of measures of similarity, the verification of the recovery and the use of the functionality of the explanation and, finally, the implementation of independent applications. The main focus of methods in this category is to find similarity between cases [21].

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 that offers the opportunity to easily connect an ontology in the CBR application to use it, for case representation and content-based reasoning methods to evaluate the similarity between them [22]. However, at the same time, it ensures sufficient flexibility to enable expert users to implement advanced CBR applications.

The use of structured representations of cases requires approaches for the evaluation of similarities that allow to compare two objects structured in different ways, in particular, objects belonging to different classes of objects. The use of structured representations of cases requires approaches for the evaluation of similarity that make it possible to compare two differently structured objects, in particular, objects belonging to different classes of objects. An important advantage of similarity box retrieval is that if there is no case that exactly matches the requirements of the user, this may show cases that are more similar to your query.

The recovery strategy used in our system is the correlation technique. Correlation is a bivariate analysis that measures the strengths of association between two variables. A line that crosses all the data points and has a positive slope represents a perfect correlation between the two objects. In statistics, the value of the correlation coefficient varies between +1 and -1. When the value of the correlation coefficient is approximately  $\pm 1$ , then it is said to be a perfect degree of association between the two variables [23]. As the value of the correlation coefficient goes to 0, the relationship between the two variables will be weaker, Fig. 5.

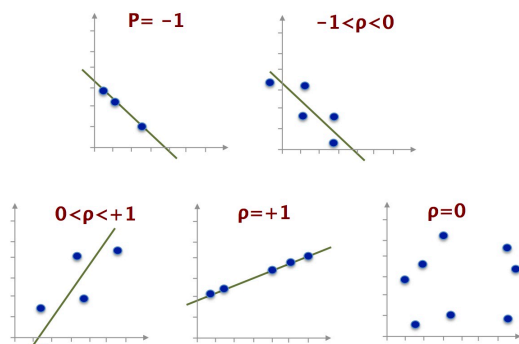


Fig. 5. The method generates a line of best fit between attributes on two data objects.

In our prototype we measured the correlations with the Pearson correlation method. Pearson's coefficient is a more complex and sophisticated approach to finding similarity. This best fit line is generated by the Pearson coefficient, which is the similarity score. The following formula is used to calculate the Pearson correlation:

$$\rho_{x,y} = \frac{\text{cov}(X,Y)}{\sigma_x \sigma_y} = \frac{E[(X - \mu_x)(Y - \mu_y)]}{\sigma_x \sigma_y}$$

Where:

- $\underline{r}$  = Pearson r correlation coefficient
- N = number of value in each data set
- $\sum xy$  = sum of the products of paired scores
- $\sum x$  = sum of x scores
- $\sum y$  = sum of y scores
- $\sum x^2$  = sum of squared x scores
- $\sum y^2$  = sum of squared y scores

Pearson's correlation is widely used in statistics to measure the degree of relationship between linear related variables. For example, if we want to measure how two products are related to one another, Pearson's correlation is used to measure the degree of relationship between the two raw materials. The coefficient is found by dividing the covariance by the product of the standard deviations of the attributes of two data objects. The advantage of the Pearson Coefficient over other techniques is that it is more robust against data that is not standardized. For example, if a person gives the range of movies "a", "b" and "c" with scores of 1, 2 and 3 respectively, it has a perfect correlation with someone who rated the same movies with 4, 5, and 6.

## 4.2 Case knowledge base.

Semantic models can greatly improve the usefulness of information obtained through operations integration solutions. As a result, understanding provided through semantic models is fundamental to being able to correctly drive the correct ideas of supervised instrumentation, which can ultimately lead to optimizing business processes or, in this case, industry services. In the physical network a control point such a port or temperature sensor is known by its identifier in a particular control system, possibly through a label name such as Port-R115.

The CBR case data could be considered as a part of the knowledge, that is, resource metadata. Metadata descriptions of resources and objects



of knowledge and the development of the knowledge base. Protégé provides an environment for the creation and development of underlying semantic knowledge structures-ontologies and semantically annotated web services. Protégé organizes these elements as a dynamic workflow process.

After designing the ontology, we write the classes and the description of the properties in the semantic markup language RDF [28]. Then, the domain expert, in this case the administrative staff, populates the blank units of the instance according to the knowledge of the domain. 7,000 cases were collected for user profiles and their different resources and services. Each case contains a set of attributes related to both metadata and knowledge.

## 6 Experimental intelligent control platform

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 management knowledge into the network resource specifications. We studied an example of alarm detection and intelligent problem solving. We have used a network belonging to a company in the electricity sector Sevillana-Endesa (SE) and Spanish electricity company. OntoNetwork is used to optimize the operation of hundreds of connected sensors currently installed. The Spanish grid has a wireless network in the regional high voltage grid. These inexpensive wireless sensors and accompanying analytics can drastically improve plant performance, increase safety and pay for themselves in a matter of months [29]. Using agent knowledge integration can help the system administrator use 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 because of the management limitations of the network communication equipment. SCADA consists of different subsystems, the remote terminal units (RTUs) that connect sensors in the process, converting sensor signals into digital data and sending digital data to the monitoring system. The communication infrastructure that connects the monitoring system to the RTUs and a monitoring computer system, gathering the data acquisition process and sending control commands to the process [30].

OntoNetwork monitors the main parameters of the network in real time, making use of the information provided by the SCADA, located in the main building of the company, and the RTUs are installed in different stations Fig. 7:

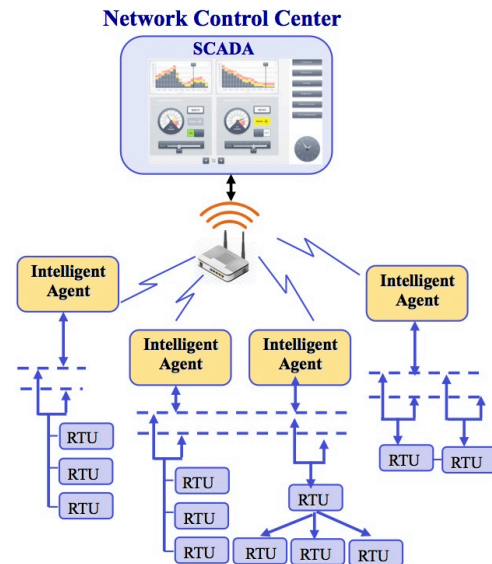


Fig. 7. Elements of the prototype.

SCADA systems are configured around standard basic functions such as data acquisition, monitoring and event processing, archiving and data storage analysis, etc. The fundamental role of an RTU is the acquisition of various types of power process data, accumulation, data conversion in a form that can be communicated back to the master, interpretation and output of commands received from the master, and performing filtering, calculating, and local processes to allow specific functions to be performed locally [31].

The following monitoring and RTUs include all network devices and substation and feeder levels such as circuit breakers, reclosers, automatic disconnectors, distributed local automation in these devices and the communications infrastructure. OntoNetwork allows the operator to search for information, alarms or digital and analog parameters of measurement, registered in each RTU. From the information provided, the operator can take action to resolve any faults that may arise or send a technician to repair the station equipment. The system has the ability to select an agent, which is the most suitable to satisfy the requirements of the client, without the client being aware of the details about the agent. Collaborative agents are useful, especially when a task involves multiple systems on the network.



## 7 Assessment and Evaluation Platform

The system test is a level where the complete and integrated architecture is tested under certain conditions. In this section, we will analyze the system's ability to offer different functionalities. OntoNetwork combines information from several intelligent points and can identify and alarm for conditions including blown fuses, broken conductors, low alerts and over voltage, etc. The system also links low-voltage network information with geographic network views through a distribution management system that provides quick and easy identification of problems and improves network operation [32].

The following Fig. 8 illustrates the results collected as part of the experiment. We have analyzed the response time question for ten agents related to network resources [33]. This graph shows that the speed of OntoNetwork improves the lead time of traditional methods.

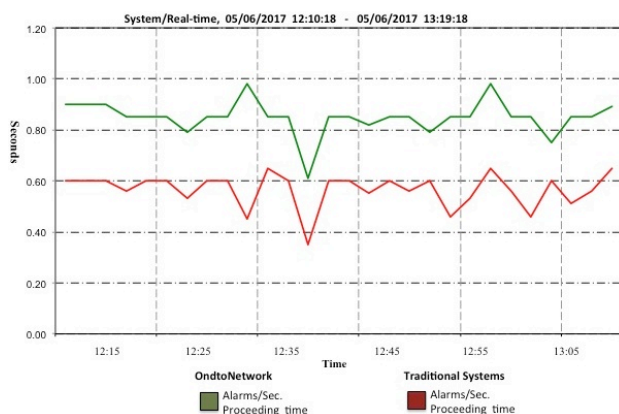


Fig. 8. Performance OntoNetwork & traditional methods.

In our field of study, we can observe that the best final classification was obtained for our prototype and an interesting improvement on the performance of other search engines. Our system works satisfactorily with a success rate of 98.5% in real cases.

We can establish that the speed of OntoNetwork in our domain improves the response time and the average of the traditional search engine. OntoNetwork results are 25.4% better than running time / sec searches on traditional search engines.

Other advantages and benefits of the OntoNetwork system:

- Synthesizes a discrete and reversible solution for detected incidents, and automatically applies the solution without human intervention.

- Uses analytics to perform the comparative analysis of the broader endpoint to detect anomalies and eliminate false positives.

- Provides extensive reporting to provide critical insight into incident and problem management activities.

- Dynamically learns and adapts to each organization's environment by gathering knowledge about past incidents in the case base.

## 8 Conclusion

This chapter explores how semantic technologies can be used to provide additional semantics from existing resources in industrial repositories. For this, we present a system based on ontology and AI architecture for knowledge management in industrial repositories. We describe an effort to design and develop a prototype to manage resources in a repository, such as the OntoNetwork project, and exploit them to help users as they select resources.

As described here, semantic models play a key role in evolving solution architectures that support the business objective of gaining a more complete picture of what is happening in operations, and then derive business perspectives from that view. Semantic models based on industry standards go one step further, especially since application providers adopt these standards (which, as always, will pass more quickly under pressure from the user community). We have investigated how semantic technologies can be used to provide additional semantics of existing resources in institutional repositories. This study addresses the key aspects of a semantic and intelligent information retrieval system architecture in an attempt to meet the requirements of the next-generation semantic search engine.

The study analyzes the results of the implementation and evaluates the feasibility of our approaches to allow the search in digital repositories based on intelligence. We introduced a prototype web-based CBR retrieval system, which operates in an RDF file store. With this feature an individual's modeling ability will be increased to learn through the collective search experience. In addition, an AI was illustrated to assist the user by suggesting better ways to query the system based on the resources in the industry repositories according to their own preferences, which come to represent their interests.

Future work will focus on the design of distributed, self-managed web-based services that will be able to automatically discover, compose and integrate heterogeneous components, manage heterogeneous data/knowledge/ intelligence sources, create, deploy and exploit bound data, to be able to



navigate and filter information based on semantic similarity, etc.

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