An Intelligent Help-Desk Framework for Effective Troubleshooting

Miguel Ángel Leal , Antonio Martín, Jorge Ropero, Julio Barbancho, Carlos León
Department of Electronic Technology
University of Seville
Seville, Spain
e-mail: maleal@us.es, toni@us.es, jropero@dte.us.es, jbarbancho@us.es, cleon@us.es.

***Abstract*— Nowadays, technological infrastructure requires an intelligent virtual environment based on decision processes. These processes allow the coordination of individual elements and the tasks that connect them. Thus, incident resolution must be efficient and effective to achieve maximum productivity. In this paper, we present the design and implementation of an intelligent decision-support system applied in technology infrastructure at the University of Seville (Spain). We have used a Case Based Reasoning (CBR) methodology and an ontology to develop an intelligent system for supporting expert diagnosis and intelligent management of incidents. This is an innovative and interdisciplinary approach to knowledge management in problem-solving processes that are related to environmental issues. Our system provides an automatic semantic indexing for the generating of question/answer pairs, a case based reasoning technique for finding similar questions, and an integration of external information sources via ontologies. A real ontology-based question/answer platform named ExpertSOS is presented as a proof of concept. The intelligent diagnosis platform is able to identify and isolate the most likely cause of infrastructure failure in case of a faulty operation.**

Keywords-Case Based Reasoning; Helpdesk; Artificial Intelligence; Fuzzy Logic; Ontology.

I. INTRODUCTION

Today, troubleshooting intelligent management is viewed as one of the fastest growing areas of research, while new applications are developed in decision-support systems. Some of the challenges on these systems depend on the integration of intelligent systems in existing conventional systems. Many researchers are working on these topics, but none of them have focused on normalizing the management of knowledge.

In this work, we study a technology infrastructure troubleshooting maintenance centre at the University of Seville (Spain). This paper shows how semantic web and artificial intelligent technologies can be utilized in help-desk systems from the point of view of the content indexer. We also describe an inteligent decision-based semantic service named ExpertSOS. This is an example of how to apply a semantic technique for extracting troubleshooting knowledge. Clients may send trouble symptoms or questions to the system. Then, the system provides an expert answer to these questions. Moreover, this work proposes a method to efficiently search for the expert information on an Intelligent Decision Support System (IDSS) with multiple independent information sources.

Typical work in related fields includes intelligent agents. Ottosen et al. [1] suggest a heuristic model that simulates real-world troubleshooting system. Chu et al. [2] describe how data mining technologies can be used to build a rule-based system for customer service automatically. Cebi et al. [3] propose an expert system to help shipboard personnel solving ship auxiliary machinery troubleshooting. Zahedi et al. [4] investigate fuzzy troubleshooting of a complex crude oil desalination plant. Sierra et al. [5] describe a maintenance system for a microsatellite. Abdul-Wahab et al. [6] describe a fuzzy logic-based technique to design real-time troubleshooting advice.

Although there have been great advances in intelligent troubleshooting management, very few studies investigate the use of hybrid techniques to integrate the acquired knowledge from management experience based on Case Based Reasoning (CBR) engines and ontologies. This paper presents the integration of several computational intelligence techniques in ontology search and CBR. This way, a real-time intelligent assistant has been developed to automatically find patterns for the incidents and possible solutions from the stored cases in the system knowledge database. We present a method to efficiently retrieve knowledge from an intelligent decision support system (IDSS) with a semantic source. We have designed and developed an intelligent decision support environment named ExpertSOS to assist the customer service center of a large University within the technological infrastructure. In the following sections, we review the CBR framework and its features for implementing the reasoning process over ontologies. Section 2 presents a general overview about the technology infrastructure at the University of Seville, analyzing its failures and discovering the needs that push us toward new intelligent help desk paradigms. Section 3 analyzes ontology requirements and proposes the design criteria to guide the development of ontologies for knowledge-sharing purposes. Section 4 examines the design and development of the intelligent ExpertSOS platform, while Section 5 presents the Graphic User Interface (GUI). Section 6 shows tests and results. Finally, Section 7 shows the main conclusions of our work.

II. GENERAL OVERVIEW

The historic University of Seville (UoS) is one of the top-ranked universities in Spain. The UoS has a present student body of over 75,000, 4,500 teaching staff, and 2,500 administrative staff. UoS provides a robust infrastructure utilizing state-of-the-art technologies, with 1,200 wireless access points, 55,000 laptops, and 25,000 PCs distributed in

 ISBN: 978-1-61208-576-0

the more than 30 buildings. In this scenario, UoS information systems and technology infrastructure must respond to the requirements of the community by providing additional quality functionalities. The Service of Information and Communication (SIC) of the UoS is responsible for Information Technology issues and offers technical services to the university. SIC offers a range of technical services for the university community, which include the architecture, installation, administration, and maintenance of servers; back end services, such as monitoring, updating, patches, security, data integrity assurance, and license management; computer network maintenance, including the backbone campus network, student hosting, and wireless networking. Moreover, SIC provides services such as e-mail, file storage, online courses, etc., and is responsible for maintaining all administrative applications. Due to the wide variety of technical services, resources and software that can be found, SIC has got a team of highly-trained technicians (45 workers) in the different university campus buildings. This group performs a varied set of tasks, assisting the university community with a wide range of services. The list includes, but is not limited to maintenance and monitoring resources, installation of computer equipment, security, monitoring hardware requirement assessment, virus and malware removal, hardware installation and troubleshooting, software troubleshooting, network connection issues, data recovery services, etc.

Derived from the various devices, heterogeneity and different group of programs can be found in this infrastructure, and given the lack of the standardization, the numerous devices and resources cause different types of diagnostic information when an incident occurs. Thus, the UoS installed a help desk platform named TSOS (Technical SOS). TSOS was designed to support and answer calls from customers and find the answer to their problems. A call center was responsible for receiving reports on faulty machines, or inquiries from their customers. When a problem is reported, a TSOS service engineer suggests a series of "checkpoints" to the technicians to solve the reported problem. Such suggestions are based on past experience or extracted from a customer service database. The database contains previous service records that are identical or similar to the current one. When an online session cannot solve the problem, the service center will dispatch the service engineers to the customer's site as soon as possible, in order to carry out an onsite repair. This traditional tool has limited functionalities. Three major problems are identified:

1) Choosing the appropriate index terms for a question–answer pair is often time consuming and difficult.

2) There are different conventions in indexing. As many people are taking part on it, the content is eventually unbalanced. For example, a technician may use a few general index terms to describe an answer, whereas another one may use a larger amount of specific terms.

3) No system gathers the experience gained during the actions. Thus, this information is not available to the other technicians.

With the advent of technology, it is now feasible to provide effective and efficient help desk service over a global platform to meet the technicians' requirements. Thus, we present a method to efficiently retrieve knowledge from an Intelligent Decision Support System (IDSS) with a semantic source. The IDSS plays a significant role, offering a wide range of realistic possibilities for assistance with incidents. Instead of asking for the help of a desk technician, or searching through the Internet for an answer, with the intelligent help desk system, the technician just must describe the problem and the agent may automatically search the appropriate knowledge bases. Finally, the system presents a consolidated answer, being the most likely in the first place. An intelligent help desk can help finding and filtering information. The IDSS can handle complex problems, applying domain-specific expertise to assess the consequences of executing its recommendation [7]. In addition, the decisions supported by the IDSS tend to be more consistent, and better managed in terms of managing uncertainty in the outcome.

A. System architecture

Our objective is to design an effective intelligent system with an ontology mapping mechanism for troubleshoot computing environment. ExpertSOS is a research tool built to explore the possibilities and the potential of introducing ontologies into decision-support systems. With ExpertSOS, it is possible to capture, understand and describe the knowledge on troubleshooting in a technology infrastructure. This intelligent system, running on a server, is programmed using PHP/MySql, it captures the domain expert knowledge in Troubleshooting FAQ (Frequently Asked Questions) process into the knowledge base. ExpertSOS is an integrated tool within an incident management system.

Based on these characteristics, we have created an intelligent decision system named ExpertSOS for providing automated decision analysis assistance in the management of failures. The system allows technicians and engineers to quickly gather information and process it in several ways, in order to make an intelligent diagnosis and arrive at an efficient solution. This is achieved by using intelligent and knowledge-based methods. The system architecture is shown in Figure 1.

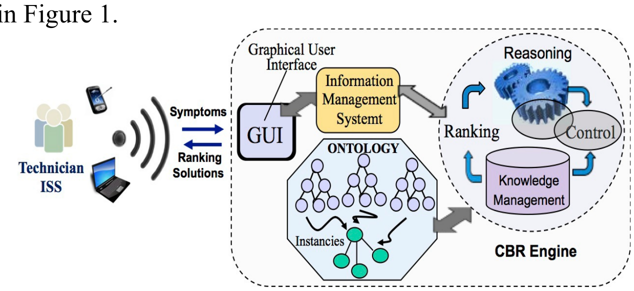

Figure 1. System Architecture.

The elements of the system are the following:

– A user interface: for queries and case knowledge acquisition. This module is mainly for acquiring case-related knowledge so as to build up and maintain databases such as the case library, the ontology library, the similarity matrix library and the global vocabulary library [8].

– A CBR engine: When users input case attributes, this processes the computing algorithm and prompts with similar cases for reference.

– A case knowledge sharing converter: the major function of this module is to offer standards for the translation and the mapping of domain knowledge elements.

III. ONTOLOGY DESIGN AND DEVELOPMENT

The effectiveness of fault management is heavily dependent on the algorithms that are available for diagnosing and determining the source of a problem. Knowledge management is concerned with the representation, organization, acquisition, creation, use, and evolution of knowledge in its many forms. Nowadays, there are different techniques commonly used to manage the knowledge, such as topology analysis, rule-based method, decision tree, dependency graphs, code book technique, Bayesian logic approach, neural networks, etc. However, these techniques find it difficult to catch the semantic meanings of the user requests and the cases stored in the knowledge base. For this purpose, it is necessary to include capabilities to capture the semantic meanings of the managed information and data [9].

In this work, we use a hybrid technique, which consists of a CBR system and ontology. Our IDSS architecture operates through ontologies for knowledge acquisition to allow learning and reasoning. This higher level of understanding can be achieved through processing of the information based on semantics, which is not possible by considering a document as a bag of words. Semantic technologies are usually based on ontologies and play a central role in semantic applications by providing a shared knowledge about the objects in real world. Ontologies are specifications of concepts and relations among them and provide a powerful way to organize information. Ontologies promote reusability and interoperability among different modules and their main goal is to support the interchange of information [10]. This work follows an iterative development process in the ontology-engineering phase and defines the ontologies needed to be used together with the current application.

B. Case type attribute

In order to make an ontology-based intelligent retrieval, we need to build a case knowledge base with inheritance structure.

We developed these ontologies in Ontology Web Language (OWL), by building hierarchies of classes describing concepts and relating the classes to each other using properties. We also used the Resource Description Framework (RDF) to define the structure of the metadata, describing knowledge management of the incidents and the Semantic Web Rule Language (SWRL) to specify rules that validate the defined constraints. In order to express this model, we have created an ontology called OntoSOS, based on pairs Question–Answer (QA), and explicitly specifying the relationships between the ontology classes. The ontology and its sub-classes are established according to their taxonomies, as shown in Figure 2.

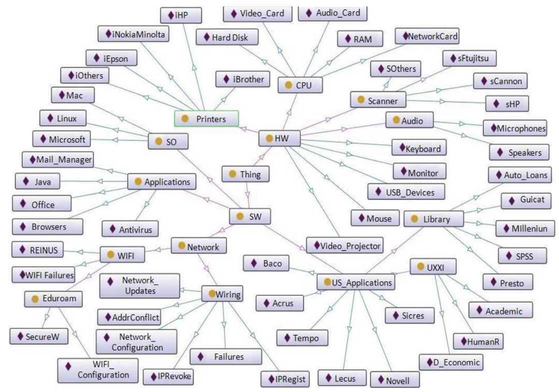

Figure 2. Ontology.

The ontology can be regarded as the quaternion OntoSOS:={technician_profile, object, symptom, action) where the profiles represent the technical kinds; the objects are the resources with the underlying problem or fault; symptoms are the indications that can be observed directly by the customer or the technician; finally, actions are associate operations to solve the problem.

C. Creation of the ontology

This work uses an ontology technique for representing information, so that CBR techniques can be used. The ontology-based architecture is made of a set of knowledge, an ontology of the domain, and intelligent access to the set of knowledge. For every request, the intelligent system searches into the cases stored in the knowledge base. The cases are grouped using a metadata language model. Retrieved cases are ranked using a semantic relevance method, and are summarized to generate optimal solutions.

First, we started with a core ontology including the basic concepts and a simple hierarchy. Then, we experimented with this ontology and fixed the issues in reasoning and searching. These steps were repeated until we ended up with a stable ontology containing 35 classes and 191 properties in the domain. When the model got large enough, we needed some tools to help for their management. Several tools may be used in this process, such as Protégé. Protégé is a software tool that supports the specification and maintenance of terminologies, ontologies, and knowledge bases. This framework is an ontology development environment that provides tools for authoring ontologies [11]. Protégé uses OWL and RDF as an ontology language to establish semantic relations. In Figure 3, we show a screenshot of the Protégé editor with a section of the ontology class hierarchy.

After the ontology is established, the case base is generated from a file store where each case is represented with RDF syntax. Knowledge for this system was taken from the expert domain through interviews and discussions. The dataset currently consists of over 7,200 QA pairs.

 ISBN: 978-1-61208-576-0

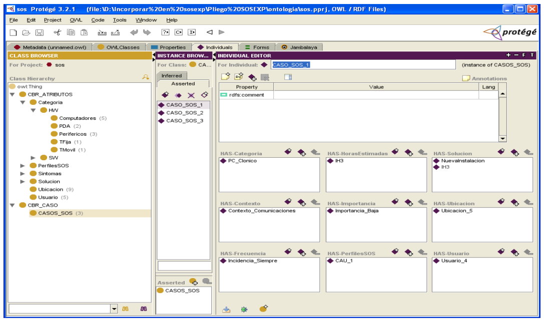

Figure 3. Prótegé Ontology Development

IV. INFERENCE ENGINE

We proposed CBR as a plausible approach to profit from the framework usage experience. When developing applications from a framework, knowledge about the way in which similar domain actions were previously implemented is very useful in order to deal with a new domain action. Thus, we developed a CBR system on framework usage experiences. CBR is a problem-solving paradigm that uses knowledge of relevant past experiences (cases).

These usage experiences explain, through a sequence of steps, how to implement concrete domain actions (incidents) using specific pieces of the framework. This knowledge acts as a prescriptive guide to the framework use and constituted the cases of our system.

Three basic tasks constitute the cycle of the CBR systems: the retrieval of the case that solves the most similar problem to the current one, the adaptation of the retrieved case when it does not exactly fit the current problem and the case learning.

In this study, we used the CBR object-oriented framework development environments jcolibri, that is conceived to help application designers to develop and quickly prototype CBR systems. Jcolibri is an object-oriented framework in Java, along with a number of supporting tools that is designed to facilitate the construction of CBR systems. Jcolibri has been designed as a wide spectrum framework able to support several types of CBR systems from the simple nearest neighbor approaches based on flat or simple structures to more complex Knowledge Intensive ones. Its broad coverage of methods used in case-based recommendation makes jcolibri specially suited for building this type of systems. A key feature of jcolibri authoring tools is the use of templates. In order to facilitate the development of systems, we have been investigating how to reuse templates that abstract past CBR systems. In order to test these ideas we have developed a case base of templates for building case-based recommender systems which effectiveness has been tested through empirical evaluation. Templates store the control flow of the CBR applications and include semantic annotations conceptualizing its behavior and expertise.

A common scenario in an intelligent help desk system is finding whether similar faults have been processed before. The intelligent diagnosis platform should be able to identify and isolate the most likely cause of infrastructure failure in case of a faulty operation. In an IDSS, a response can be defined as the activation, coordination, and management of the appropriate personnel, equipment, communication links, and user information. A potential user provides initial ideas, and possibly a description of the incident. The intelligent help system must retrieve the most likely existant cases, and a possible solution to the given incidents. The goal of the information retrieval (IR) system should be retrieving only those documents that satisfy the user needs, not a bunch of unnecessary data. To improve the efficiency of the system, an original rank algorithm has been developed. It consists of a combined method, which uses a metadata model and semantic matrix factorization to group the top-ranking cases into different categories, while reducing the impact of the general and common information contained in these cases. This method relates the similarity between strings and the calculated correlation belonging to the knowledge in the ontology, as shown in Figure 4.

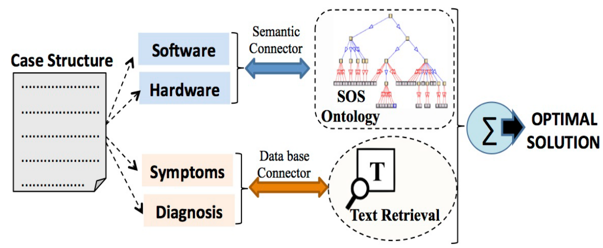

Figure 4. Knowledge Recovery scheme

The indexing algorithm provides an efficient way to search for possible solutions. The indices choice is important to retrieve the right case at the right time. ExpertSOS retrieves the cases stored in the knowledge base and ranks the retrieved cases by establishing a relevance method to the request using similarity measurement. The similarity between indications and the attributes is determined by calculating the weighted sum of the similarities between the values for each attribute.

V. GRAPHIC USER INTERFACE (GUI)

The acceptability of the system on the part of technicians depends to a great extent on the quality of the user interface component. The main goal of our GUI is to gauge the users' satisfaction and trust in the usage of a live help system. We use a simple and useful interface to achieve maximum usability and to reduce the number of ambiguous queries. Each service record consists of the customer account information and service details. A login system receives a set of credentials from the user, through single sign on (SSO) systems, which mostly use lightweight directory access protocol (LDAP) authentication. This way, technicians can interact with the system to fill in the gaps to retrieve the right troubleshooting cases. For this purpose, a keyword-based search service is available on the system, as can be seen in Figure 5.

 ISBN: 978-1-61208-576-0

Figure 5. Technical User Interface

Usually, a query is transformed into an internal form so that the system can interpret it. The raw query submitted by the user should be processed before searching. Several processing tasks can be involved, such as stop word elimination, stemming, and other application-specific tasks. Besides, the user must input the keywords in the user interface. The aim of the interface is to ease the interaction between the user and the system in a natural way. The preprocessor query module translates a query written in natural language into a high-level code. During the preprocessing stage, a query is splitted into keywords, constants, identifiers, operators, and other small pieces of text that the language defines (tokens). Syntactical analysis is the process of combining the tokens into well-formed expressions, statements, and programs. In ExpertSOS, the case-ranking module - the past cases - are ranked based on their semantic importance to the preprocessed input request. During the semantic analysis, the symptoms, values, and other required information about statements are recorded, checked, and transformed. Moreover, a domain-specific semantic dictionary to keep the synonyms has been designed. The required QA pairs should contain some knowledge about the queries and its related issues. Apart from searching and ranking the relevant cases, the system groups the top-ranking cases into categories. Finally, the cases are sorted according a score, so that the most relevant cases are presented to the user at the top of the retrieval list. The system must retrieve an object that contains the service engineer's description of the machine fault, and another object that indicates the suggested actions or services to be carried out. An example is shown in Figure 6.

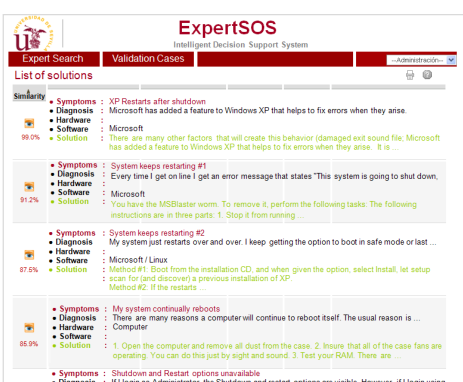

Figure 6. Search engine results

When the solution is generated, it is necessary to validate if that solution is correct. The answer contains a brief summary for each case as a reference solution to the technician. Changing the values that are proposed by the system to other values that are similar, is used to revise the correction of a solution. Each case contains a set of attributes concerning both the metadata and the knowledge. ExpertSOS provides the QA indexer with a list of possible index terms as ontological references. We used a computational-based retrieval system where numerical similarity functions are used to assess and order the cases regarding the query. With this aim, we first need to recover the similar cases from the knowledge base and then propose a new solution to solve the present problem in an efficient way. If the solution generated by the similar values is not better than the proposed one, then the chosen one is a good solution for the problem. Semantic algorithms are used to revise the correction of new solutions. After running those algorithms, the solutions can be accepted and added to the case base.

VI. PERFORMANCE TESTS

In order to compare the ExpertSOS efficiency with the traditional help desk system TSOS, we have compared the resolved incidents using ExpertSOS with those that had been resolved with the TSOS system. Figure 7 shows the total number of incidents across the years up to the end of 2014. We observe a negative trend in the number of incidents resolved using TSOS, while the number of incidents was increasing and how the ExpertSOS improves this negative trend with the implementation of an intelligent help desk system.

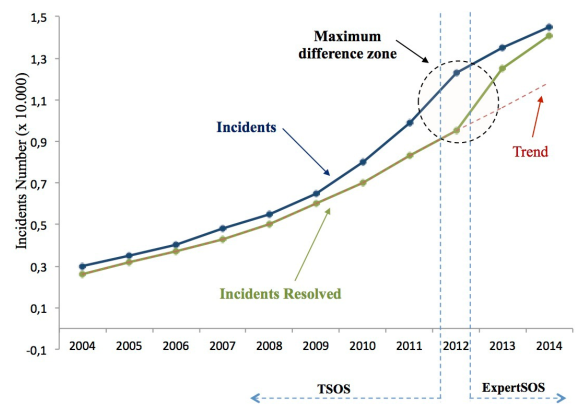

Figure 7. Performance of ExpertSOS and traditional help-desk

Thus, ExpertSOS, based on CBR and ontologies has proved to be cost effective. The benefits stemming from the use of semantic web technologies in the troubleshooting context can be recognized in the following services:

- ExpertSOS has proven to be effective in reducing troubleshooting time, secondary incidents, and environmental impacts.. Increasing speeds and capability during troubleshooting can decrease the incident response time and save over 12% in the daily performance of a service.

 ISBN: 978-1-61208-576-0

- Improved knowledge distribution: Knowledge is distributed in a better way and moved from the expert technicians to the novel technicians, improving the overall solving and dispatching capability.
- Composing new cases compliant to the requirements of a particular user out of the available resources and resource solution automatic interaction dynamically adapts to the features of the particular user.
- Higher service quality, higher customer satisfaction. Furthermore, knowledge can be maintained easily and directly used. This flexibility allows for a quick response to dynamic technological and standards fluctuations.
- Increased first time resolution: Technician groups can access to the right knowledge at the right time to solve incidents quickly and efficiently. Because of this, more productive human capacity in each line was achieved.

VII. CONCLUSIONS

The technology infrastructure of universities and institutions needs the integration of different methods and techniques for developing knowledge management systems. This way, the effectiveness of management activities is increased. There is a strong need to provide support for a whole range of technicians. Different technicians have different needs and skills. An intelligent semantic help desk has been developed to assist and advice new technicians or computer users, in order to diagnose problems in the technological infrastructure of a university. In this paper, we have used computational intelligence and ontologies techniques to integrate the knowledge of incident management in a troubleshooting system. ExpertSOS serves an educational user community, helping people with different skills. Ontologies are applied for extracting knowledge, building up an IDSS. Technicians send symptoms and queries to the system, which provides an expert answer about the question. This work focuses on three aspects to enhance knowledge retrieval: how to apply CBR to find existing similar QA-pairs for a newly submitted question; how to utilize relevant information services to support answers; and how to use semantic indexing to help choosing the appropriate index terms for QA pairs.

For this purpose, our platform is focused on providing expert solutions, delivering exceptional technician service, and creating a reliable infrastructure. We have used a CBR system structure to provide a systematic and analytical troubleshooting procedure. The intelligent help desk described in this work is capable of learning, generalizing, and self-organizing information, in order to find complex patterns and assist in decision support. The main contribution is the described approach for the integration of knowledge from different sources and metadata characterizations of the QA pair in a help desk system to achieve semantic interoperability. This method has a positive effect on technician interpersonal development, such as an enhanced sense of personal efficacy, and the development of technical skills.

The use of computational intelligence and ontologies as a knowledge representation formalism offers many advantages in Information Retrieval. Ontologies and CBR technologies provide a solid solution as an ontology gives an explicit definition of the shared concepts of a certain domain. In fact, the ontology constrains the set of possible mappings between queries and their answers.

Finally, the study analyzes the implementation results and evaluates the viability of our platform. The experimental results shows that the proposed approach can achieve high retrieval accuracy and can considerably improve efficiency compared to existing techniques used in typical customer service systems. ExpertSOS helps to save costs in eliminating the expensive telephone charges, and the number of onsite visits by service engineers.

REFERENCES

[1] T. J. Ottosen, and F. V. Jensen, "When to test? Troubleshooting with postponed system test, Expert System with Applications, vol. 38 (10), pp. 12142-12150, 2011.

[2] B. Chu, C. Lee, and C. Ho, "An ontology-supported database refurbishing technique and its application in mining actionable troubleshooting rules from real-life databases", Engineering Applications of Artificial Intelligence, vol. 21 (8), pp. 1430-1442, 2008.

[3] S. Cebi, M. Celik, C. Kahraman, and I. D. Er. "An expert system towards solving ship auxiliary machinery troubleshooting: SHIPAMTSOLVER," Expert Systems with Applications, vol. 36 (3), part 2, pp. 7219-7227, 2009.

[4] G. Zahedi, S. Saba, M. al-Otaibi, and K. Mohd-Yusof, "Trobleshooting of crude oil desalination plant using fuzzy expert system," Desalination. vol. 266 (1-3), pp. 162-170, 2011.

[5] E. A. Sierra, J. J. Quiroga, R. Fernández, and G. E. Monte, "An intelligent maintenance system for earth-based failure analysis and self-repairing of microsatellites," ActaAstronautica, vol. 55 (1), pp. 61-67, 2004.

[6] S. A. Abdul-Wahab, A. Elkamel, M. A. Al-Weshahi, and A. S. Al-Yahmadi, "Trobleshooting the brine heater of the MSF plat fuzzy-logic based expert system," Desalination. vol. 217 (1-3), pp. 100-117, 2017.

[7] O. A. Blanson, V. M. Sawirjo, C. A. van der Mast, M. A. Neerincx, and J. A. Lindenberg, "Computer assistant for remote collaborative troubleshooting of domestic medical instruments," Pervasive Computing Technologies for Healthcare, pp. 285-288, 2008.

[8] D. Wang, T. Li, S. Zhu, and Y. Gong, "iHelp: An Intelligent Online Helpdesk System," IEEE Transactions on Systems, Man, and Cybernetics, vol.41 (1), pp.173-182, 2011.

[9] F. George, Artificial Intelligence, Structures and Strategies for Complex Problem Solving, 4ª edition, Ed. Pearson, Education Limited, 2002.

[10] C. C. Huang, and S. H. Lin, "Sharing knowledge in a supply chain using the semantic web," Expert Systems with Applications, 37(4), pp. 3145–3161, 2010.

[11] A. Gomez-Perez, A. Corcho, and M. Fernandez-Lopez, "Ontological Engineering", Advanced Information and Knowledge Processing, Springer-Verlag London, 2003.