ISSN 1870-4069

Intelligent Geographic Information System for Decision Making in the Electricity Sector

Nayi Sanchez Fleitas[1], María Matilde García Lorenzo[2], Raúl Comas Rodríguez [3], Amanda Riverol Quesada[4]

[1] Empresa de Tecnología de la Información y la Automática, Cuba

[2] Universidad Central Martha Abreu de Las Villas, Computer Science Department, Cuba

[3] Universidad Regional Autónoma de los Andes, Research Directorate, Ecuador

[4] Universidad de Cienfuegos Cuba

raulcomasrodriguez@gmail.com

Abstract. In the Electricity Union works on the development of a Geographic Information System (GIS) that has a conceptual basis and response to the different requests of the user. For this, the objective of the research is: to develop a model for the management of geospatial data, with the use of Artificial Intelligence techniques, as support to decision making in the electric sector. As a first step a light ontology is elaborated that endows the conceptual base system. To achieve the automatic queries a Case Based System is developed. The case database contains the description of static queries previously made in the form of cases and responds to a three-level hierarchical organization, which favors the processes of access, recovery and learning of cases. Each consultation consists of eleven fundamental features, of which eight are predictors and three objectives. This system is applied in all the electric companies of the country. The results of field validation evidence the feasibility of the proposal.

Keywords: electricity, GIS, case-based system, ontologies.

1 Introduction

Energy is one of the pillars of development in productive processes, the social progress, the technological advance [1], the satisfaction of the needs of people and a means to raise the standard of living of the population. The obtaining of electric power calls for a complex infrastructure.

The Electrical Union (UNE, Spanish acronym), in Cuba develops the Business Management System of the Electrical Union (SIGE), that focuses on the automation of electrical processes [2]. SIGE is composed of two main subsystems: The Integral System of Network Management (SIGERE) and the Integral Management System of the Electrical Industry Construction Enterprise (SIGECIE).

The functions of SIGERE and SIGECIE are to collect technical, economic and management data to convert them into information. The data collected facilitate and improve the efficiency in the operation, use, analysis, planning and management of the electricity distribution and transmission networks. The two systems constitute the databases of a Geographic Information System (GIS), that forms part of the SIGE.

The SIG's development begins in the 2001. The first version receives SIGOBE's name 1.0, with 220 options of quest. For the SIG's bringing up to date is join panel of experts with experience of the theme meets. An analysis of the literature is carried out and a group of experts on the subject is gathered, who detect the following limitations:

1. Rudimentary methods of n elaboration.
2. Functional relationships of the electrical system elements are not described in the database.
3. Lack of important concepts for the electrical system in the data base.

Given current information needs, interest in GIS has increased [3]and techniques and standards have been developed to ensure that everyone has access to this type of data[4].Therefore the objective of the investigation is: Developing a model for data management , with the use of techniques of artificial intelligence, on a deep conceptual scheme of dominion, that answer open into the petitions of users like support to the overtaking in the Union Electrical.

2 Paper Preparation

The development of geographic information systems is generally done focusing on a particular context and restricted to a specific domain that generates problems of interpretation. Different communities can define the same objects in different ways, according to different points of view and assumptions about the study domain, which causes communication problems due to lack of shared understanding [5]. One of the most important problems detected in the different investigations conducted are those derived from the heterogeneity and interoperability of the data [6]. For its solution, an increasingly dominant strategy in the organization of information is associated with the term "ontology" [7]. Neches argues that an ontology defines the basic terms and relationships that comprise the vocabulary of an area of interest, in addition to the rules of combining terms and relationships to extend that vocabulary [8].

The fundamental role of ontology is to structure and retrieve knowledge, to promote its exchange, and to promote communication [9].

Table 1. Representation of the network in vectorial scheme.

Points (Support Points)	Lines (Circuits)	Polygons (Substations)
Posts	Transmission Circuit	Distribution Substation
Transformer banks	Subtransmission Circuit	Transmission Substation
Capacitor banks	Primary Circuit	
Generator groups	Secondary Circuit	
Disconnectors Structures	Lighting Circuit	
Lamps		

In addition, relying solely on CBR for distributed and complex applications can lead to systems being ineffective in knowledge acquisition and indexing [10]. According to [11] use of ontologies in case-based reasoning gives the following benefits: It is an easy-to-use tool for case representation, queries are defined using daily terminology , it facilitates the assessment of similarity and it increases system performance.

Alight weight ontology is provided to the system to give a conceptual basis. In the conceptualization we have the concepts, their taxonomy and relations (objects properties); the remaining components of the ontology model (data properties, instances and axioms) are not developed, because the information is already in the database that feeds the system. The ontology was carried out using the Methontology methodology and the Protégé tool [12].

With the ontology the system is given a conceptual basis. But we still have a problem a weakness of the systems proposed is in the dissatisfaction with the queries carried out. If a static inquiry is developed for each problem that arises, the database begins to store a group of scarcely-used queries. In order to solve the problem, the system must be able to generate intelligent queries in real time, in which the knowledge obtained from previous ones is used.

Artificial Intelligence (AI), is the branch of computer science that attempts to reproduce the processes of human intelligence through the use of computers [13]. Within AI, the Expert Systems (ES), or Knowledge Based Systems (KBS), emerged in the 1970s as a field that deals with the study of: the knowledge acquisition, its representation and the generation of inferences about that knowledge.

In this sense, CBRs appear as a palliative to the process of knowledge engineering and are based on the premise that similar previous problems will have similar solutions [14].

With this principle as the basis, the solution to a problem is retrieved from a memory of solved examples. For each case, the most similar previous experiences that allow finding the new solutions are taken into account [15, 16]. Case-based reasoning contributes to progressive learning, so that the domain does not need to be fully represented [17]. The CBRs have three main components: a user interface, a knowledge base and an inference engine [18].

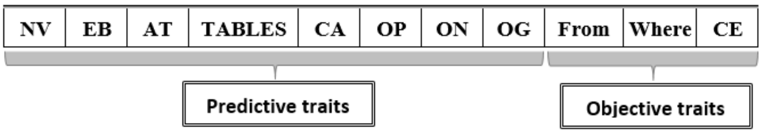

Fig. 1. Cases structure.

An analysis of the inquiries carried out, including those for SIGERE, allows establishing the structure of a case to solve the problem, which is divided into predictive traits and objective traits (Figure 1). For a better understanding of the proposed structure, in the Table 1 identifies the universe of discourse of the predictive and objective traits.

SIGERE and SIGECIE are considered complex systems that have 36 modules in use, and a database of: 716 tables, 1303 procedures stored and 74 functions. In addition, other functionalities are in development phase. An action on transformers involves approximately 9 tables that have more of 150 different attributes. These actions are represented in the case base only for 6 queries.

The NV trait determines the database to reference (SIGERE or SIGECIE), deletes a group of installations and sets the final scale at which the results are displayed. For example, the transmission process involves several provinces, subtransmission several municipalities of a province, while the rest of the levels are located within a single inhabited place.

The EB trait represents the classification of the basic elements of the electric network according to their correspondence of their characteristics in the vectorial scheme. Table 2 shows the representation of the basic elements according to their characteristics in points, lines and polygons.

The ontological traits ON and OG, represented by descriptive logics, have the greatest weight within the case. A possible value of the ON trait would be: T ∩ TPot ∩ TMonofasic -- SSecondary This range expresses that the element is a monophasic primary transformer with no secondary output. OG works similarly, but their relationship is spatial.

In the present research, a hierarchical structure is used because it favors the system in the process of access and retrieval to the most similar examples to the real time query. For this, an analysis of the traits is performed taking into account which allows discriminating more options in each case. In the Figure 2 shows the organization of the case database where:

1. the predictor trait NV is the root node;
2. in the second and third level the EB and OP traits are added, respectively, since they are the most discriminative elements;
3. in the leaf nodes, sub-sets of cases that represent those examples where the value of NV, EB, OP match.

Table 2. Universe of discourse of predictive and objective traits.

Trait	Possible values	Type
	Predictive traits	
NV	Secondary, Primary, Subtransmission, Transmission	Symbolic and single-valued
EB	Posts, Transformer banks, Capacitor banks, Generator groups, Disconnectors, Structures, Lamps, Transmission Circuit, Subtransmission Circuit, Primary Circuit, Secondary Circuit, Lighting Circuit, Distribution Substation, Transmission Substation	Symbolic and single-valued
AT	Attributes to be returned by the inquiry (code, voltage, name, etc ...)	Set
Tables	Tables of the SIGERE involved in the inquiry (Accessories, Actions, Connection, Interruptions, Line, CurrentSupplyPrimary, etc ...).	Set
CA	Element to compare (Attribute being compared)	Symbolic and single-valued
ON	Operator ($\cup$, $\cap$, $\leq$ $\geq$ =, like , etc)	Symbolic and single-valued
OP	Ontology (descriptive logic) $\mathrm{T} \cap \mathrm{TP} \cap \mathrm{TMonophase} \neg \mathrm{SSecondary}$	Ontology
OG	Spatial constraint (descriptive logic)	Ontology
	Objective traits	
From	Returns the From of the inquiry to the SIGERE	String
Where	Returns the Where of the inquiry to the SIGERE	String
CE	Returns the GIS inquiry	String

2.1 Inference Engine

The recovery module is responsible for extracting from the case database the case or cases most similar to the current situation.

Global similarity is the result of the weighted sum of the distances between the value of each trait in a case and the value that it acquires in the problem case. This similarity is determined by equation 11. The distances are weighted considering the expert criterion. The most important traits are the ontological ones:

$$\mathrm{SimGlobal}(\mathrm{bc_j}, \mathrm{P}) = \sum_{i=0}^{8} \mathrm{w_i} * \mathrm{d_i}(\mathrm{bc_{ji}}, \mathrm{P_i}) \Big/ \mathrm{n}. \tag{1}$$

Table 3. Results of SICUNE by area.

Queries	Total	Correctly	Bad	Retain	%
Office	230	221	9	23	96,08%
Engineering department	189	178	11	40	94,18%
Customer service area	147	140	7	18	95,23 %

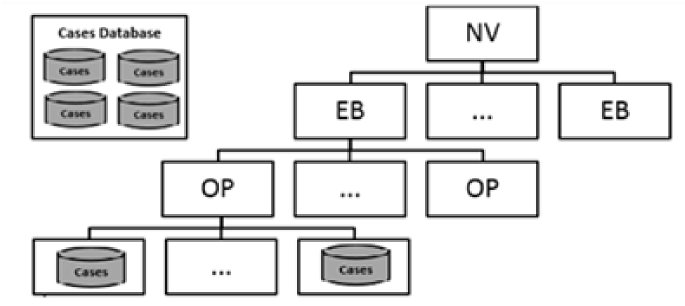

Fig. 2. Cases database structure for the UNE.

Local distance is determined by the type of data of the traits. In the case presented here there are three types of data for which different distance measures are used that are described below.

The traits NV, EB, CA and OP are symbolic single-valued type, the distance used is of Boolean type. The AT and Tables traits are of the set type. As a result of the tests performed on the system, the Jaccard distance is implemented.

The OG and OE traits represent the general and spatial ontologies. The similarity measure that give the best results based on a control sample and a field test was the Jaro-Winkler distance.

$$d_i(bc_{ji}, P_i) = \begin{cases} d_i(bc_{ji}, P_i) = \begin{cases} 0 \text{ Si } bc_{ji} == P_i \\ 1 \text{ Si } bc_{ji} \neq P_i \end{cases} & i = 1,2,5,6, \\ d_i(bc_{ji}, P_i) = \frac{|bc_{ji} \cap P_i|}{|bc_{ji} \cup P_i|} & i = 3,4, \\ d_i(bc_{ji}, P_i) = \frac{1}{3}\left(\frac{c}{|bc_{ji}|} + \frac{c}{|P_i|} + \frac{c - t/2}{c}\right) & i = 7,8. \end{cases} \quad (2)$$

3 Results

SIGOBE is national in character and is applicable to the different areas that divide electricity companies. It offers a group of facilities such as:

1. Locate complaints from the population, a failed installation or with abnormal parameters,
2. organize the tour of the cars, display customer voltages on the map,
3. make a study of equipment faults in rural areas,
4. optimize the use of networks and optimize their use,
5. at certain scales allows drawing the sketch of new projects with the necessary accuracy.

With the development of the ontology, it achieves greater efficiency in the software. For the implementation of the RBC was developed within SIGOBE the module SICUNE (Intelligent System of Consultation for the UNE); Which uses the transformational analogy on previously made queries, retrieved by a case-based reasoned, to answer user questions.

The stage of retention of cases is in preliminary phase since the current size of the base of cases does not presuppose reissues of the cases because it still results of average size. New cases are needed as new SIGERE modules are developed.

4 Experimental Study

To test the SICUNE, three departments of an Electric Company are selected that use information from different areas of the database and achieve greater coverage in the information contained. The work of these areas is operational and needs the functionality proposed for their daily work:

1. Office,
2. Engineering department,
3. Customer service area.

In all three areas, SICUNE tests are carried out for a period of one month for its validation. Table 3, shows the results by area.

The general results of the application of the SICUNE, with an effectiveness of 95.23%. In order to strengthen SICUNE, it is necessary to incorporate new cases, especially those related to the engineering area, due to the complexity of its work.

5 Conclusions

The following conclusions can be made:

1. A case-based system on type problem solver was designed, using as an initial case database, the 265 static queries registered in SIGERE. The queries are described by eight data-type predictive traits and three objective traits. The case database responds to a three-level hierarchical organization, which favors the processes of access, recovery and learning of cases.
2. The similarity between two cases was determined by the weighted sum of the distance of their traits.

3. In the research was developed ontology for the processes of distribution and transmission of electrical energy.
4. The case retention stage is in preliminary phase, since the current size of the case database does not presuppose reissues of cases, because it is still medium-sized.
5. An intelligent real-time queries system is implemented for the UNE (SICUNE), achieving the generation of automatic queries that allow the system to respond to any type of queries in real time.
6. The experimental study shows the feasibility of the proposal.

References

1. Castillo, Y., Gutiérrez, M. C., Vanegas-Chamorro, M., Valencia, G., Villicaña, E.: Rol de las Fuentes No Convencionales de Energía en el sector eléctrico colombiano. Prospectiva, 13, pp. 39–51 (2015)
2. Fernández-Álvarez, R.: Informatización de la Gestión de las Redes Eléctricas. Tesis Doctoral, Facultad de Ingeniería Eléctrica (2011)
3. Yusoff, A., Abdullah, S., Din, N. M.: A Taxonomy on Knowledge-based Geographical Information System (GIS) for a Cloud-based Disaster Management Environment. The 3rd National Graduate Conference (NatGrad) (2015)
4. Carrera-Calderón, F. A., Martínez-Vargas, M. Á.: La Accesibilidad Web en el Proyecto de Infraestructura de Datos Espaciales – GTIDE CEDIA, UNIANDES EPISTEME. Revista de Ciencia, Tecnología e Innovación, 3 (2016)
5. Durango-Vanegas, C. E.: Asociación de datos espacio-temporales en bases de datos Oracle, Ingenierías USBmed, 5, pp. 100–108 (2015)
6. Machado-García, N., González-Ruiz, L., Balmaseda-Espinosa, C.: Recuperación de objetos geoespaciales utilizando medidas de similitud semántica. Revista Cubana de Ciencias Informáticas, 8, pp. 132–143 (2014)
7. Smiraglia, R. P.: Domain Analysis for Knowledge Organization Tools for Ontology Extraction. Elsevier (2015)
8. Neches, R., Fikes, R. E., Finin, T., Gruber, T. R., Senator, T., Swartout, W. R.: Enabling technology for knowlege sharing. AI Magazine, 12, pp. 36–56 (1991)
9. Myrgioti, E., Bassiliades, N., Miliou, A.: Bridging the HASM: An OWL ontology for modeling the information pathways in haptic interfaces software. Expert systems with applications, 40, pp. 1358–1371 (2013)
10. Akmal, S., Shih, L. H., Batres, R.: Ontology-based similarity for product information retrieval. Computers in Industry, 65, pp. 91–107 (2014)
11. Bouhana, A., Zidi, A., Fekih, A., Chabchoub, H., Abed, M.: An ontology-based CBR approach for personalized itinerary search systems for sustainable urban freight transport. Expert systems with applications, 42, pp. 3724–3741 (2015)
12. Sánchez-Fleitas, N., Comas-Rodríguez, R., García-Lorenzo, M. M., Riverol-Quesada, A.: Modelo de manejo de datos, con el uso de inteligencia artificial, para un sistema de información geográfica en el sector energético. Enfoque UTE, 7, pp. 95–109 (2016)
13. Russell, S. J., Norvig, P.: Artificial Intelligence. A Modern Approach. Englewood Cliffs (1995)

14. Gillespie, K., Gupta, K. M., Drinkwater, M.: Case-Based Object Placement Planning. International Conference on Case-Based Reasoning, pp. 170–184 (2014)
15. Moreno-Laverde, R., Joyanes-Aguilar, L., Giraldo-Marín, L. M., Duque-Méndez, N. D., Tabares-Morales, V.: Modelo para personalización de actividades educativas aprovechando la técnica de Razonamiento basado en Casos (RbC), 4, pp. 118–127 (2015)
16. Wimmer, H., Rada, R.: Good versus bad knowledge: Ontology guided evolutionary algorithms. Expert systems with applications, 42, pp. 8039–8051 (2015)
17. Fitzgerald, T., McGreggor, K., Akgun, B., Thomaz, A., Goel, A.: Visual Case Retrieval for Interpreting Skill Demonstrations. 23rd International Conference, (ICCBR) (2015)
18. Cordero-Morales, D., Ruiz-Constanten, Y., Torres-Rubio, Y.: Sistema de Razonamiento Basado en Casos para la identificación de riesgos de software. Revista Cubana de Ciencias Informáticas, 7, pp. 222–239 (2013).