Vol. 4, No. 2, pp. 12-17, December 2005

INTERNATIONAL JOURNAL OF SAFETY
www.kosos.or.kr

Electrical Fire Cause Diagnosis System based on Fuzzy Inference

Jong-Ho Lee* and Doo-Hyun Kim

Department of Safety Engineering, Chungbuk National University, Chungbuk 361-763, Korea

(Received August 27, 2005; Accepted December 10, 2005)

Abstract : This paper aims at the development of an knowledge base for an electrical fire cause diagnosis system using the entity relation database. The relation database which provides a very simple but powerful way of representing data is widely used. The system focused on database construction and cause diagnosis can diagnose the causes of electrical fires easily and efficiently. In order to store and access to the information concerned with electrical fires, the key index items which identify electrical fires uniquely are derived out. The knowledge base consists of a case base which contains information from the past fires and a rule base with rules from expertise. To implement the knowledge base, Access 2000, one of DB development tools under windows environment and Visual Basic 6.0 are used as a DB building tool. For the reasoning technique, a mixed reasoning approach of a case based inference and a rule based inference has been adopted. Knowledge-based reasoning could present the cause of a newly occurred fire to be diagnosed by searching the knowledge base for reasonable matching. The knowledge-based database has not only searching functions with multiple attributes by using the collected various information(such as fire evidence, structure, and weather of a fire scene), but also more improved diagnosis functions which can be easily used for the electrical fire cause diagnosis system.

Key words: case base, rule base, knowledge-based reasoning, electrical fire cause diagnosis, entity relation db, fuzzy inference

1. Introduction

Electricity is energy that becomes a motive power of life and industry. Demand for electrical power is increasing every year because of its convenience and stability. Thus electrical devices become more various and complicated. However, the electrical fires take place in spite of a rapid progress in electricity and development in protective devices. Electrical fires are of common occurrence all over the world, causing severe damages to property and loss of human life. For last several decades with the achievement of fast economic development, the electrical fires occupies over 30 percent of total fire incidents almost every year in Korea and is not decreased in spite of much times and efforts. Among several causes of fires, the electrical causes take the highest proportion as compared with any other fire causes. Short circuits and overload are one of the major causes of these fires. When unwanted short or arcing occurs, it generates high temperatures that can ignite nearby combustibles such as wood, paper, and carpets. Some of these fires are caused by electrical system failures and appliance defects, but many more are caused by the misuse and poor maintenance of electrical appliances, incorrectly installed wiring, and overloaded circuits and extension cords[2].

The diagnosis of electrical fire causes may be approached either by studying electric facilities or by investigating causes using precision instruments at the fire scene. However, cause diagnosis methods for electrical fires haven't been systematized yet. Also the fire investigators have a difficulty in accomplishing the diagnosis task because there is no perfect and easy technique for the diagnosis. Investigator's mistake for the diagnosis is happening because of diagnosis limit for available information and investigator's biased knowledge. In order to establish detailed plans for fire protection and reduce the possible electrical fires in the future, the collection and database construction of domestic and foreign electrical fires and fundamental analysis for accident case, fire investigation report, cause investigation methods etc, are very important job. Therefore required is research for electrical fire cause diagnosis

*Corresponding author: yijho@korea.com

system can produce diagnosis results with high reliability. In order to develop the electrical fire cause diagnosis system, the construction of a knowledge database which can be used in inferring the electrical causes in the system should be precede.

In this study, a knowledge base using a PC-based database program, which can be adopted to diagnose electrical fires easily and efficiently, was developed to make electrical fires to be diagnosed easily and efficiently. Using the collected information concerned with electrical fires, the key index items for the efficient storage and access of them are classified and derived out as follows : basic condition, fire scene condition, fire evidence and fire causes. For the reasoning technique, a mixed reasoning approach of a case-based reasoning and rule-based reasoning has been adopted.

2. Electrical Fire Investigation

The fire investigation methods remain in a relatively low level by contrast with the fact that the number of fires increases year by year. As a result, people who lost their home and their property from fire had to suffer with the insufficient investigation results. When a fire occurs, suspicion of its cause often falls on any electrical equipment present, in part because of the basic fact that electricity can cause heat and heat can cause a fire. Because most structures contain electrical wiring or electrical apparatus of some sort, electricity-related causes are often suspected. Some investigations focus on electrical causation for no better reason than suspicion based on misunderstanding and mythology[3-4].

The National Emergency Management Agency appears to show that about 30% of fires are 'electrical' in origin, but this hides multitude of sins. Also electrical fire statistics are made by the fire reports of form which ask for the 'supposed cause' to be filled in. Electrical fire proportion of each country shown in Table 1. This may be completed by a fire officer who has had no training in the investigation of fire and to whom the finding of a burnt piece of electrical cable showing short circuit arc marks is clear proof of electrical causation, whereas it is almost certainly the result of a fire having burnt through the energized cable. Second, a number of fires are reported as 'electrical' if they occur through misuse of an electrical item. Thus a fire caused by the ignition of clothes placed too close to an electrical radiant heater may be categorized as electrical.

The extent of the misreporting can be seen form a recent survey of fires perfectly investigated by the investigator(fire officer etc). This survey showed that only a little of these fires were actually caused by electrical fires. It could be argued that as the fire office was only called in to investigate fatal or suspicious fires, these fires were biased away from accidental causes. It might be expected that if electricity was a major cause of fire this would show through in electrical fire statistics, but electrical fire causes were found to account for only 70% of the electrical fires examined. And it is often put to the prosecution investigator by defense lawyers that the fire was actually caused by an electrical fault. Thus the investigator has not carried out the fire scene examination properly by having missed the true cause[4].

A fire investigation is a complex endeavor involving skill, technology, expertise and science. The compilation of factual data, as well as an analysis of those facts, should be accomplished objectively and truthfully. By nature of fires, such as complex, random, probabilistic etc., it is often impossible to perfectly determine how the fire to be investigated and diagnosed. A laboratory reconstruction is of particular value to an electrical fire investigation, but reconstructions will always be expensive and will nearly always be resource limited, both in money and time. Because all electrical fire incidents are different, all reconstructions are different, and so it is almost impossible to fully plan ahead. Therefore it is alternative to diagnosis the causes by similar incidents and rules based on investigator's knowledge on the database, with full records and documentation.

3. Knowledge Base for Cause Diagnosis

The knowledge base consists of a case base and a rule base. The case base for the case-based reasoning in diagnosing electrical fire causes contains many cases of fire investigation reports with documented experience for fires investigation. The rule base for the rule-based reasoning for electrical fire cause diagnosis is a set of

Table 1. Electrical fire proportion over countires

Section	Korea	Japan	New Zealand	America	Taiwan	England
Proportion(%)	34.0	11.8	5.6	18.9	13.7	7.0
Year	2001	1999	1999	1998	1999	1999

'IF-THEN' rules derived from the experiences of fire investigators and other experts, knowledge from fire case analysis, etc. In fact, these two bases can be used independently for making a diagnosis of electrical fire cause based on knowledge based reasoning.

In this paper, these two bases for diagnosis are combined together to infer the electrical fire causes with improved accuracy. The knowledge base for the electrical fire cause diagnosis was implemented with entity-relational database model using Access 2000, one of DB development tools under windows environment, and Visual Basic 6.0 is used as a DB building tool. The entity-relationship model is based on perception of a real world that consists of a collection of basic objects, called entities, and of relationships among these objects.

3.1 A Case Base

A case base is designed to match the newly occurred fire case with the past fire cases stored in a database by a kind of pattern recognition. In other words, the reasoning in the case base uses past experience as a basis for dealing with physical evidence relating to the cause of the electrical fires. It can solve problems by evaluating problem, explaining exceptional instances or comprehending new instances by using past cases and experiences. It is easier to acquire fire cases than to obtain rules from fires.

A case base is constructed by the collected fire investigation reports. The cause classification model for electrical fire diagnosis in this paper was newly developed by the comparison of the classification model of National Fire Protection Association(NFPA) and one of Japan. Fire data classification model for the case base construction contains; criteria items, which are based on the raw data obtained from the fire investigation reports and used as attributes at a special data storage format called 'Table' in Access 2000, were categorized by the elements common to all electrical fires to characterize them. Items for the case base construction are classified : basic condition, fire scene condition, fire evidence and fire cause. A case-based reasoning for cause diagnosis of electrical fires is the process of finding cause from the case base as a temporal cause for reasoning causes of new fires[5-7].

3.2 A Rule Base

A case-based reasoning for cause diagnosis has its limitations. It has difficulty in expressing concepts which can be easily understood by people, case-based reasoning is always sensible to uncertainties, and it is short of good case adaptation mechanism In most circumstances case-based reasoning process is can't ensure the good performance of the cause diagnosis and needs other technique as supplement. There is a techniques, called rule base, which may be integrated into case base. Although both case base and rule base have been successfully applied, they have their own shortcomings respectively. One of the challenges is how to combine expert's knowledge and fire cases and how to make both work cooperatively. Thus we consider the combination of rule base and case base as a good mode, and it is probable to make up deficiency of the respective drawbacks of the two methods and to make full use of their good points.

At present there has been some mixed case base with rule base. The rule base includes a computer-assisted fuzzy diagnosis and inference rules from expert's knowledge and fuzzy theory. A fuzzy intelligent architecture is based on the uncertain entity-relational database model. The causes of most electric fires were studied and the fire investigation reports are surveyed to get the exact relationship and fire causes and physical evidences. However it is figured out that there are lots of uncertainties which can have effects on the diagnosis results. To cope with this problem, it is requisite to introduce a fuzzy inference architecture as a principle of the electrical fire cause diagnosis. The classes include fuzzy IF-THEN rules to define knowledge, and the fuzzy membership based on possibility theory is used for representations of vagueness and uncertainty. Rules with linguistic terms are used to describe the relationship between attributes such as fire evidences. Therefore, introduced and described is a rule-based reasoning along with its fuzzy inference mechanism. A fuzzy inference method is used for deduction reasoning of fuzzy conclusions.

The knowledge-based database is critical to the cause diagnosis system, and Entity Relation Database Management System(ERDBMS) is used for the database system. Particularly, the fire cause category is classified by ignition source and causes. Using a new classification for cause diagnosis, the knowledge-based database system which can be used to infer the fire causes by the combined approach of case-based reasoning and rule-based reasoning efficiently, has been developed in this paper.

4. Inference on Knowledge Base

The knowledge base for the electrical fire cause diagnosis system consists of a case base including the existing fire cases and a rule base including intelligent

objects having fuzzy attributes and rules. The knowledge base is used for handling knowledge about cause reasoning. The inference to confirm fire causes is conducted on the knowledge-based database by combined approach of a case-based reasoning and a rule-based reasoning. Knowledge-based reasoning could complete case searching by adjusting a newly occurred case and a set of rules for reasonable matches. On the developed knowledge base, introduced is combined reasoning of pattern matching on the case base and fuzzy inference on the rule base.

In case-based reasoning for electrical fire cause, each existing fire case is stored as a record at 'Table', alongside its known causes in a relational database, and the records make finally the case base. This case base is reviewed in making a diagnosis for each new electrical fire. In general, a diagnosis using case-based reasoning is a two-stage process. Initially, the new electrical fire to be diagnosed is compared with the stored fire cases in the case base in order to find the exactly coincident case or the most similar case. Afterwards comes the adaptation phase, in which the diagnoses of the similar case(s) are adapted for the new fire, resulting in fire causes relevant to the new fires. Therefore, the similarity between cases plays a key role in constructing and maintaining case-based reasoning.

In order to reduce electrical fires and establish detailed prevention plans, the collection of electrical fire causes and basic data from scene investigation are very important. And the knowledge representation for case-based reasoning is important to characterize fire cases exactly. The case base memorize the past diagnosed results, need not reason step by step from the very beginning, thus improved efficiently when diagnose the newly occurred fires. The schema diagram of case base using the entity relation databases shown in Fig. 1. The case-based reasoning for electrical fire diagnosis system consists of three main components; a knowledge representation which contains cause relating to the fire evidence, an inference engine which provides the control and matching mechanism for the cases in the database, and an explanation mechanism to explain why the diagnosis result is reasonable. The conceptual structure of the case-based reasoning is depicted in Fig. 2.

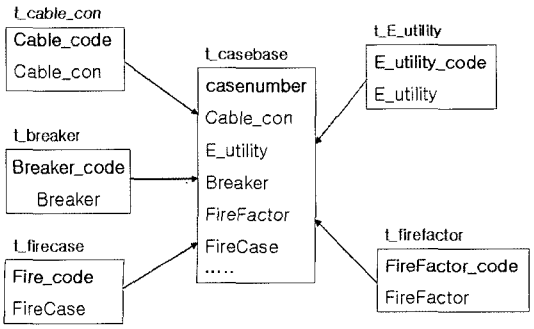

Fig. 1. Schema of Data structure in the Case Base

In rule-based reasoning, a fuzzy inference engine is used for deduction reasoning of fuzzy conclusions. Knowledge is represented by IF-THEN rules in which the antecedent and the consequent involve linguistic variables[8-9]. The antecedent of a rules may be composed of more than one clause connected by the fuzzy logical operators AND and OR.

IF u is A and v is B „„ THEN y is Z

where 'u is A' and 'v is B' are linguistic variables of fire evidences or physical evidences, 'y is Z' is linguistic variables of fire causes. And the antecedent part as well as the rules are represented using fuzzy numbers given by membership functions. For rule-based access and vague query evaluation, the usual access methods are no longer available. Thus, the need arises for efficient index structures capable of dealing with membership function data and a entity relation database. That is, superimposed coding, which was proposed for pattern matching retrieval, is a very promising approach for building an efficient index structure for relation database. In rule-based reasoning, the collection of rules from expertise and the evaluation of fuzzy membership are critical steps to get reasonable results. The schematic diagram for electrical fire diagnosis system based on fuzzy inference on rule base and pattern recognition on case base shown in Fig. 3.

5. Results

The knowledge-based database was basically focused on DB construction not only to have searching functions with multiple attributes to support maximal various input requirements of the user but also to have more rapid diagnosis functions. The knowledge base DB adopted a technique that makes entities into data-

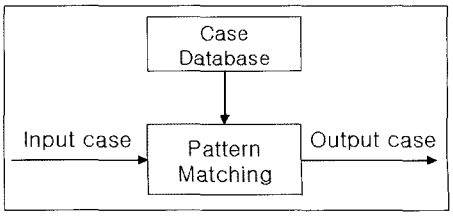

Fig. 2. Conceptual structure of the case-based reasoning

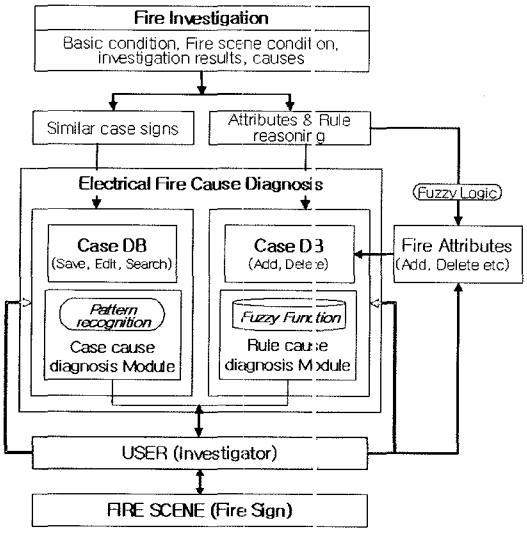

Fig. 3. Schematic diagram for electrical fire diagnoisis system based on fuzzy inference

base, and then showed some significant functions supported by query language. Also we suggest a new spatiotemporal database query language, entitled as STQL, which made users to enable to manage efficient historical information as well as spatial management function on the basis of relational query language, SQL. Also the proposed STQL showed their operations in spatiotemporal database.

The knowledge base using Entity Relation DB stored, as entities, all fire attributes from the existing fires and fire investigation reports, etc. In case of a database, the entities might include modules, functions and design documents. Each entity expressing fire attributes was defined by a class, which specified the entity's composition as a set of typed attributes. These attributes defined structural relations among entities.

In the processing of a relation database query, the electrical fire cause diagnosis system which combines case-based reasoning and rule-based reasoning, may often need to access a large amount of data for the user to retrieve or update a diagnosed fire information. Electrical fire diagnosis system based on the knowledge base DB shown in Fig. 4. Electrical fire cause diagnosis coding with knowledge base shown in Fig. 5.

The electrical fire cause diagnosis system using case-based reasoning and rule-based reasoning shown in Fig. 6 and Fig. 7, respectively. The knowledge base is typically accessed by several types of query which may require different sets of attributes. The diagnosis system using the base identified the key parameters, i.e. ignition source, wire conditions, fire factor, etc., to search the cause of a newly occurred fire and proposed the

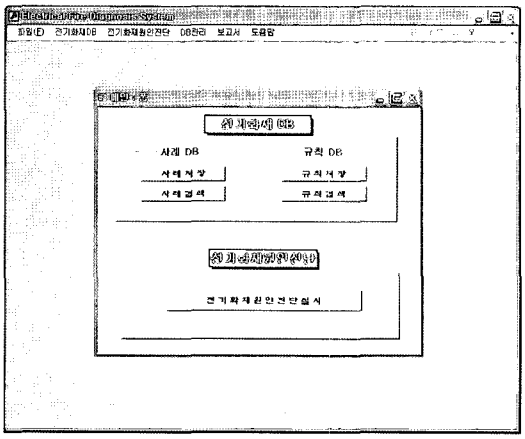

Fig. 4. Electrical fire cause diagnosis system with the knowledge base

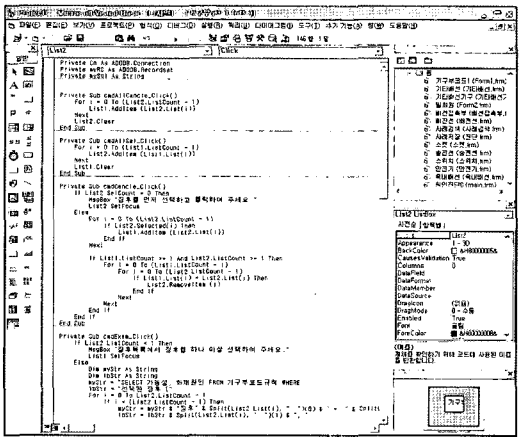

Fig. 5. Electrical fire cause diagnosis coding with knowledge base

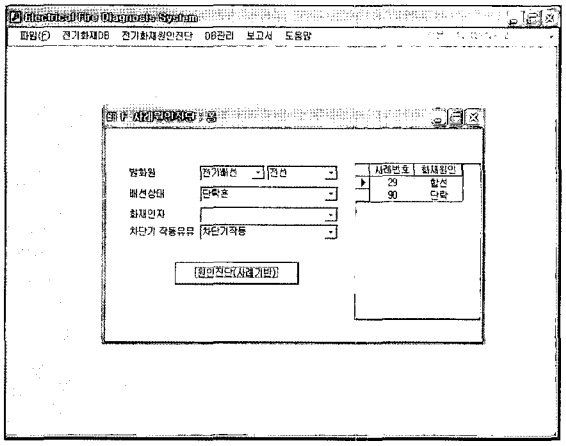

Fig. 6. Beginning window for case-based reasoning

solutions by two steps, one is a query analysis step to search the parameters recursively and the other is a data expression step to show the results of the first step.

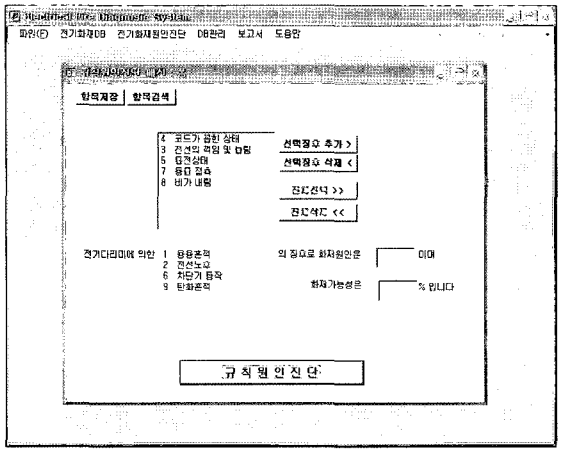

Fig. 7. Beginning window for rule-based reasoning

When the new fire enters the diagnosis system, the diagnosis process is taking place. The system proposes the causes obtained from the diagnosis process and showed good results of electrical fire causes. For other more dramatic cases of fires that the system can't present the causes by regular searching, a word scan or a monosyllabic scan based on a query analysis is used, the results of which often lead to substantial ones.

6. Conclusions

This paper discusses on the knowledge base for developing electrical fire cause diagnosis system which combine case-based reasoning and rule-based reasoning. A developed knowledge base, a kind of database which consists of a case base and a rule base, was used to analyses electrical fires easily and efficiently. This database provides the capability to assess if a database contains information pertinent to a subject of fire sign, and to exclude the irrelevant portion of the database. Each contents of the rule base are evaluated via a fuzzy evaluator that attributes a fuzzy membership value indicating its relationship between fire causes and physical evidences.

1. The developed knowledge base is used for the electrical fire cause diagnosis by the combined reasoning of a case-based reasoning and a rule-based reasoning.

2. The knowledge base database for cause investigation is constructed using experiences of fire investigators and other experts, knowledge form fire cases analysis, etc.

3. The electrical fire cause diagnosis system is based on knowledge base and fuzzy inference engine, consisting of algorithms for manipulating the knowledge on the base and functioning as consultant for investigators.

4. The developed knowledge base and cause diagnosis system can be used as education tools for training for electrical fire investigators and the related workers.

Acknowledgements

This research was supported by the Power Industry Foundation Fund of the Ministry of Commerce, Industry and Energy in Korea.

References

[1] NFPA 921 Guide for Fire and Explosion Investigations 2004 edition, NFPA, 2004.

[2] Fire Investigation Team compilation, Fire cause investigation method for the scene work, Incheon Metropolitan Fire and Disaster Management Department, 2003.

[3] John D. Dehaan, Kirk's Fire Investigation 5th Edition, Prentice Hall, 2004.

[4] Niamh nic daeid, Fire Investigation, CRC Press, 2004.

[5] Youg-Kee Paek, Jungyun Seo, and Gil-Chang Kim, A Case-Based Reasoning Approach to Relation Database Schema Design, 1994.

[6] Zhi-Wei Ni, Shan-Lin Yang, et al., Integrated Case-Based Reasoning, Proceedings of ICMLC, pp.1845-1849, 2003.

[7] G. Dvir, G. Langholz, M. Schneider, Matching Attributes in a Fuzzy Case Based Reasoning, 1999.

[8] M. Koyuncu, A. Yazici, A Fuzzy Knowledge-Based System for Intelligent Retrieval, IEEE Trans. Fuzzy Syst., Vol.13, No.3, 2005.

[9] Lawrence O. Hall, Rule Chaining in Fuzzy Expert Systems, IEEE Trans. Fuzzy Syst., Vol.9, No.6, 2001.