Realization of Embedded Diagnosis System for Air-Conditioners and Refrigerators

YIH-HER YAN[1] CHUN-HUI WU[2] WEI-YU LAI[1]
[1]Department of Electrical Engineering
National Formosa University
[2]Department of Information Management
National Formosa University
64, Wen-Hwa Rd, Huwei, Yunlin, 63201
TAIWAN
melody@nfu.edu.tw

Abstract: - The main purpose of this study is to establish a diagnosis system for air-conditioners and refrigerators by means of the programmable system on chip (PSoC) and data mining techniques. This study employed the decision tree algorithm to discover the implicit rules of air-conditioner and refrigerator troubles from examination data that is composed of normal and fault information. A diagnosis model was then extracted and its decision rules were written on the PSoC. This system has an automatic adjustment mechanism for diagnosing various types of air-conditioners and refrigerators and has the capability of communicating with computers via RS232 interface. Finally, the interface, designed with LabVIEW language, of the proposed system can monitor 256 air-conditioners simultaneously by using only one computer. In addition to providing repair methods for troubleshooting, this interface also integrated multiple functions including data saving, network linking, data querying, and warning message.

Key-Words: - PSoC, data mining, eEmbedded diagnosis system, decision tree

1 Introduction

Refrigeration and air-conditioning are indispensable in everyday life for modern society. Unpredicted outage and tedious repair and restoring time of refrigerators and air-conditioners possibly result in unpredictable cost and harm, such as spoiled food, heat-stroke, winter-kill and so on. Therefore, reliable and stable refrigeration and air-conditioning are becoming essential issues in terms of good life quality.

With regard to air-condition system, it can be categorized into constant air volume (CAV), variable air volume (VAV), variable refrigerant volume (VRV) systems and so on. In this study, the CAV system air-conditioner was selected as the experiment platform for fault diagnosis. This is because that the prevalence of CAV system employed in the air-conditioner during early period for keeping the temperature of freezer or freezing room. Moreover, these kinds of equipment are seldom replaced in general. Therefore, it will be much more significant to establish a fault diagnosis system for this widely-used type of air-conditioner and refrigerator and the operation efficiency can be improved accordingly. The diagnostic system will be performed in real-time base and keep the operation under optimal status, thus alleviating the damage owing to equipment faults. In consequence, the purpose of this study is to develop a diagnosing system for refrigeration and air-conditioning which encompass the capability of recognizing normal or abnormal conditions of system operation and transmitting the fault information to the maintenance staff via internet along with the associated fault type, fault origin, examination scheme and repairing procedure. In this way, the maintenance staff can recognize the fault details in advance and prepare necessary tools and parts for fast and efficient problem-solving.

2 Theoretical Fundamentals

For establishing diagnosis system, it is indispensable utilize the data mining technique to analyze gathered data. Based on the collected and compiled information, the diagnosis model can be established and employed onto fault diagnosing system. This kind of procedure is normally called Knowledge Discovery in Database (KDD).There are six steps in this procedure, including data collection, data pre-processing, data storage setup, data mining, sample assessment, and results demonstration.

Wherein, data mining in knowledge unveiling process stand for the application of data classification to perform the data analysis. The fundamental theory for modeling is based on decision tree and k-means method. There exists no apparent conceptual discrepancy between these two methods and the principles of them are described as follows:

2.1 Decision Tree [1-2]

This method is one of the representatives of supervised classification. It employed the known results to establish classification structure. According to the measurement of information theory, the binary classification is continually performed depending on the data attributes.

This study made use of decision tree C5.0 (ID3) to set up model which classified the data according to the measuring of information gain attribute. This classification is featured that more information with more randomness, less definite outcomes will be achieved. Conversely, less information with less randomness will lead to much more definite outcome. Written in Eq. (1) is the information gain formula:

$$Gain(A) = I(p,n) - E(A) \qquad (1)$$

Where,

$$I(p,n)=\begin{cases}-\dfrac{p}{p+n}\log_2\dfrac{p}{p+n}-\dfrac{n}{p+n}\log_2\dfrac{n}{p+n}, & if\ \ p,n\neq 0\\ 0 & , if\ \ p,n\ only\ one=0\end{cases}$$

$$E(A)=\sum_{i=1}^{v}\frac{p_i+n_i}{p+n}I(p,n)$$

p : number of positive instance

n : number of negative instance

A : some attribute

2.2 k-means Method [1-2]

This method is one of the representatives of unsupervised classification which did not take the outcomes into account. The advantage is there is no need of numerous output nodes. The computation complexity can, therefore, be reduced drastically. But, improper selection of cluster center might affect its classification effectiveness and decrease the classification reliability.

The total shift of k-means method is expressed as Eq. (2). Assuming that there are n data points which will be divided into k clusters without connection, the endeavor is to keep the data points having equal shift distance with their associated cluster centers.

$$E=\sum_{i=1}^{k}\sum_{x\in S_i}\|x - m_i\|^2;\ m_i=\frac{\sum_{x\in S_i}\vec{x}}{|S_i|} \qquad (2)$$

Where,

x : $data\ point$

m_i : $cluster\ centre\ of\ cluster\ S_i$

$|S_i|$: $amount\ of\ data\ points\ in\ S_i$

Fig. 1 illustrates the executing procedures of k-mean method which is sequentially divided into six steps. In this example, there are five data points and k is set to be two.

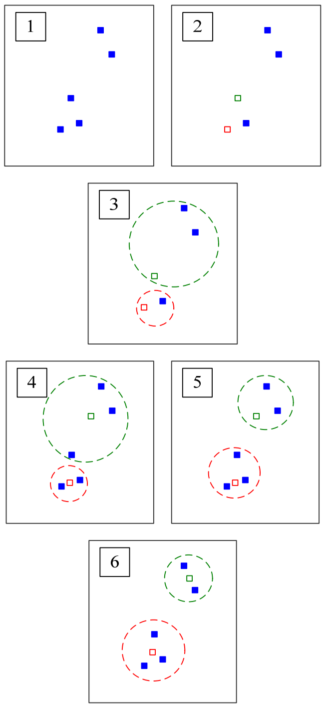

Fig. 1 Classification procedures of k-mean method

By employing Eq.(2), the cluster with shortest distance attribute can be calculated. Thus, it is not until the shortest distance was found, the distance measurement should be performed continually to check it the sampled data possess the shortest distance with their corresponding cluster centers.

3 Research Methodology

To accomplish the fault diagnosis system for refrigeration and air-conditioning, the associated mechanisms include hardware structure, system program, and human-machine-interface. The flowchart in Fig.2 is exhibited to illustrate the hierarchy of the developed embedded diagnosis system.

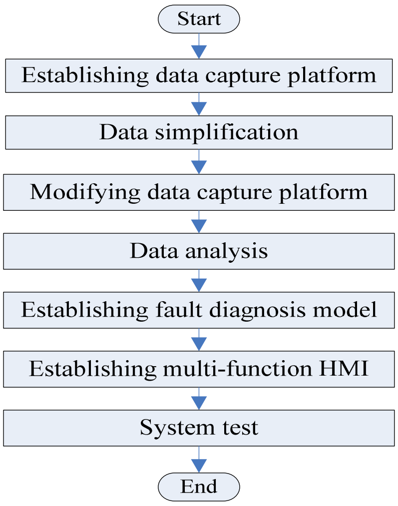

Fig. 2 Embedded system building flowchart

3.1 Establishing data capture platform

The captured data can be stored to perform data mining analysis. As shown in Fig.3, the platform comprises refrigeration and air-conditioning equipment, temperature sensor, pressure sensor, wattmeter and computer and is used to perform data storage.

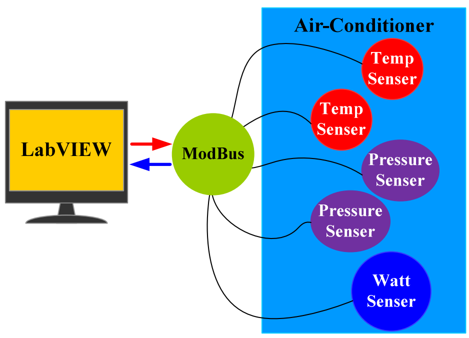

Fig.3 Data capture platform

Wherein, the sensing devices ought to be installed at inlet/outlet of compressor, outlet of condenser, inlet of evaporator, inlet/outlet of circulating water, power source terminal, and so on, with 11 entities of data in total. As the apparatuses are operating, collecting bulky operation data including normal and fault conditions.

3.2 Data Simplification

By utilizing the k-mean method, the grouping of normal and fault data can be simplified and used to set up a table. In Fig.4, the temperature data are grouped based on various statuses. Moreover, the distribution patterns are listed as well to create temperature data simplified table.

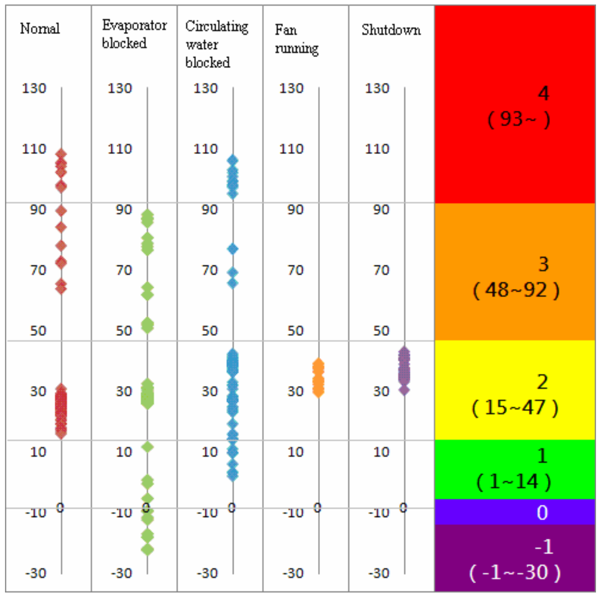

Fig. 4 The simplified table of temperature data for various *k*-Mean statuses

After accomplishing the simplified table of temperature, pressure and power consumption data, operating information can be further applied with simplified table and classified as those demonstrated in table 1.

Table 1 Numbering of various statuses

Status	Type
Air-conditioner normal (compressor running, fan running)	1
Air-conditioner normal (compressor stops, fan running)	2
Evaporator blocked (compressor running, fan running)	3
Circulating water blocked (compressor running, fan running)	4
Circulating water blocked (compressor stops, fan running)	5
Circulating water blocked (overheat tripping)	6
Wind	7
Shutdown	8
Manual shutdown	9
Power disconnected	10

By employing simplified table, data can be organized and classified, thus leading to easier fault modeling by means of supervised classification method, as is demonstrated in Fig.5.

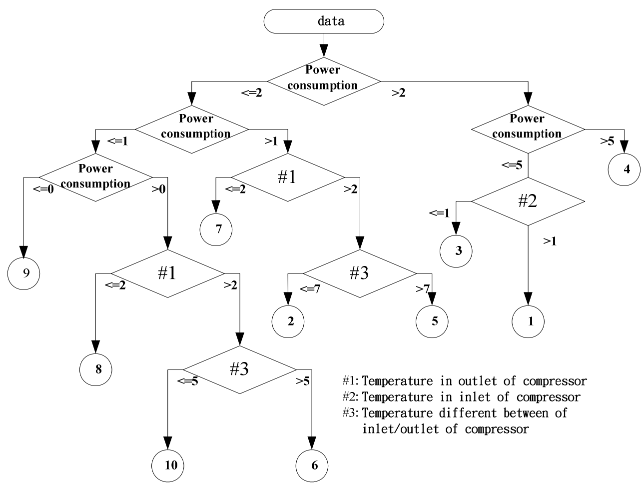

Fig.5 Fault diagnosing model of decision tree

The value of decision tree is drastic reduction of amount of sensors while featured with drawback of fixed model. When the ambient temperature fluctuates, the accuracy will be influenced. Consequently, utilization of its superiority and improvement of disadvantage are crucial in modeling.

3.3 Modifying data capture platform

Rearranging data capture platform with four temperature sensor chips (TMP275) and Hall-effect devices (LA-150P) in combination with Programmable System on Chip (PSoC), the embedded system is established and can communicate with PC via RS-232 interface, as displayed in Fig.6.

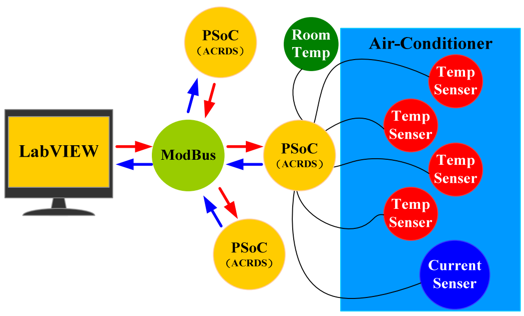

Fig. 6 Embedded data capture platform

3.4 Establishing fault diagnosis model

If single detected could lead to one corresponding fault case, it is called characteristic factor in this study. By permuting these factors in network, a network type fault diagnosing model is, then, established. Wherein, the characteristic factors must make use of boundary value to decide correct or incorrect judging points, as that shown in Fig.7.

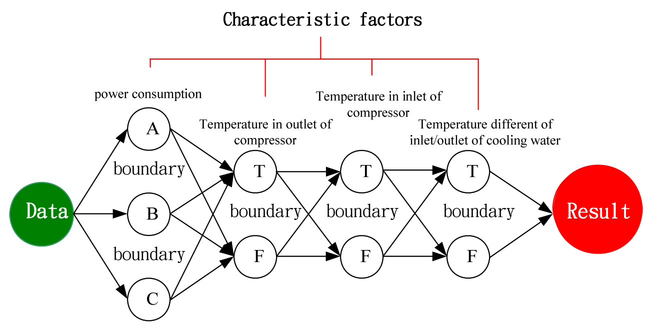

Fig.7 Network fault diagnosis model

3.5 Establishing multi-function Human-machine-interface

The multi-function comprises measured data display, imported information diagram, data base accessing, fault diagnosis message, real-time webpage browsing, and fault message warning. Fig.8 illustrates functions of the real-time webpage browsing and fault message warning. The additional interfaces will be described in the following system test section.

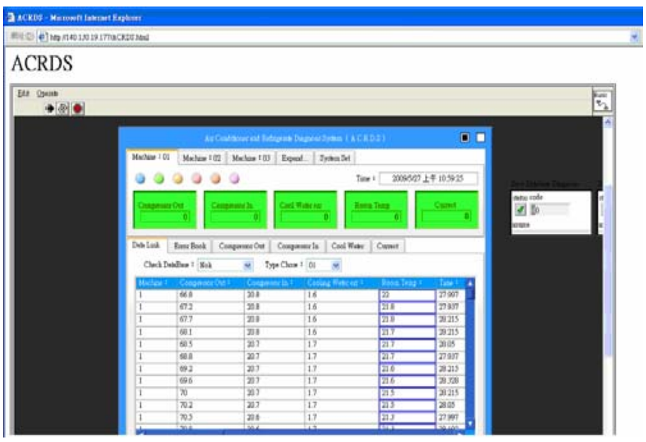

Fig.8 Real-time monitoring webpage

3.6 System test

Based on the model structure, the assessment can diagnose 24 fault statuses, with single faults and complicated faults included. The statuses will be assorted in sequence with normal, single fault (evaporator block), complicated fault (evaporator and circulating water block) to perform the experiments and exhibit the associated results by referring to Figs. 9 to 14.

(1) Air-conditioner works normally

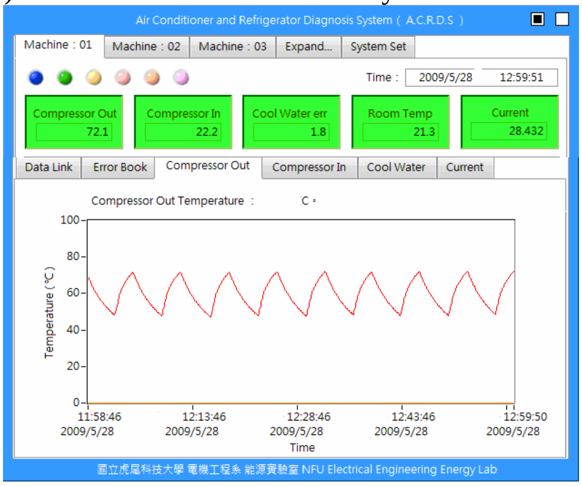

Fig.9 Diagnosis page when air-conditioner works normally

Fig.10 Embedded system message for normal

(2) Block in evaporator fault

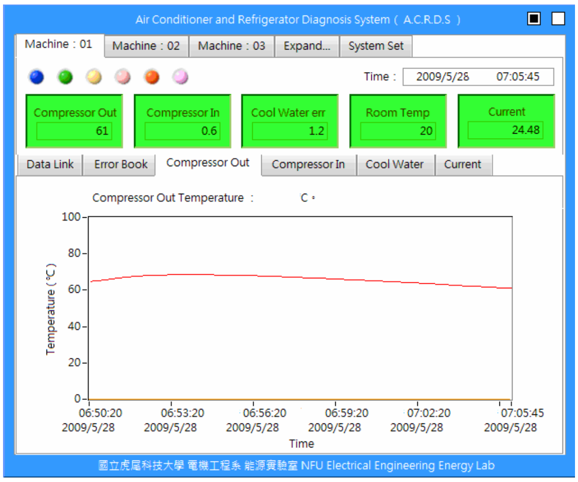

Fig. 11 Webpage for diagnosis of evaporator block

Fig. 12 Embedded system diagram for evaporator block

(3) Evaporator and circulaing water block fault

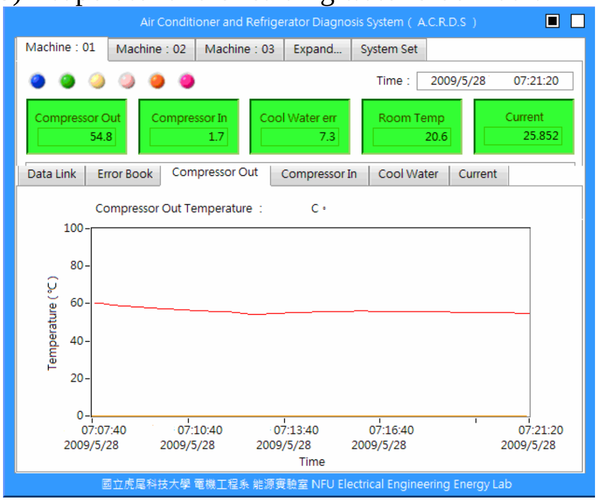

Fig. 13 Webpage for diagnosis of evaporator and circulaing water block

Fig. 14 Embedded system diagram for evaporator and circulaing water block

4 Conclusions

This paper proposes a fault diagnosing system and structure building strategy for refrigerators and air-conditioners. By replacing the traditional-used pressure sensors with temperature sensors, the decision tree method recommends to install temperature sensors on compressor inlet/outlet, circulating water inlet/outlet, and power source terminal. The fault diagnosis can be accomplished accordingly. Besides, by finding out fault characteristics of air-conditioners and establishing fine tuning fault diagnosing model, the proposed diagnosis system can adapt to other air-conditioning equipments easily merely by fine tuning. Moreover, the complete fault diagnosing model was written into Programmable System on Chip (PSoC) along with temperature sensor (TMP275), a single personal computer can monitor and diagnose a plenty of air-conditioning equipments. A low-cost, high efficiency, expandable, and comprehensive fault diagnosis embedded system is achieved and realized.

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