ISSN XXXX XXXX © 2019 IJESC

Research Article Volume 9 Issue No.4

A Framework for Personal Computer Hardware Fault Diagnosis and Maintenance

Mr. Mulugeta Shitie[1], Dr. Million Meshesha[2]
Department of Information Technology[1], Department of Information Science[2]
Debark University, Ethiopia[1]
Addis Ababa University, Ethiopia[2]

Abstract:
Computer hardware fault is the basic reason for several computer system faults in the industries. To address this problem, this study attempts to design a framework for personal computer hardware fault diagnosis. The required knowledge is acquired from domain experts, previous solved computer hardware fault cases and other relevant documents through semi-structured interview and document analysis. The domain experts are selected from university of Gondar ICT support staff and lab technicians by using purposive sampling, and then the cases are organized in attribute-values dimension and converted to plain text file for building case base. Attributes are represented using the CBR developmental tool, jCOLIBRI framework for implementing the four "Re's" (Retrieve, Reuse, Revise and Retain) of CBR application tasks. The performance of the prototype system is evaluated using precision and recall and user acceptance (satisfaction) techniques. Thus, the system has a recall of 79% and precision of 74% performance. Moreover, the system achieves 88% user acceptance by domain experts.

Keywords: case-based reasoning, computer hardware fault, Knowledge based system

1. INTRODUCTION

In today's world almost everybody is using a computer to do their job, and some of the organizations are providing a personal computer or laptop for their staff. This is showing that a computer is becoming very important in running the day-to-day activities of a business Computer hardware fault is the basic reason for several computer system faults in the industries and the majority of errors encountered on a computer are caused by hardware, and not software [1]. Hardware faults are most deadly because it affects our daily routine and our job. The widespread use of computers makes the computer hardware maintenance as a problem that cannot be ignored and must be solved. The causes of computer hardware fault are summarized and the specific maintenance methods are provided for diagnosing computer hardware faults [1]. Knowledge based system (KBS)is one of the major family members of the AI group [3]. With availability of advanced computing facilities and other resources, attention is now turning to more and more demanding tasks, which might require intelligence. The society and industry are becoming knowledge oriented and rely on different expert's decision making ability. Indeed, KBS can act as an expert on demand without wasting time, anytime and anywhere. With the proper utilization of knowledge, the knowledge based systems increase productivity, document rare knowledge by capturing scare expertise and enhances problem solving capabilities in most flexible way [3]. There are different ways of representing knowledge in the knowledge base; the two of such techniques are cases and rules [2]. Rules represent general knowledge of the domain, whereas cases represent specific knowledge. Rule based systems solve problems from scratch, while case based systems use pre-stored situations to deal with similar new instances[3]. Case-based reasoning (CBR) methodology provides a foundation for a new technology of building intelligent computer aided diagnoses systems. It addresses the challenges that are found in the rule-based technology since it provides adaptation solution by reasoning from analogy of past cases and also supports scalability by allowing adding knowledge [2].

2. STATEMENT OF THE PROBLEM

Today, the use of computer is widespread. However, the knowledge in computer troubleshooting is limited, and this poses difficulties among organizations when faced with computer problems. Computer hardware fault is the basic reason for several computer system faults in the industries and the majority of errors encountered on a computer are caused by hardware, and not by software [1]. A fault in computer equipment results in not only the loss of productivity but also timely services to customers, and may even lead to safety and environmental problems. This emphasizes the need of maintenance in manufacturing operations of organizations. A computer technician or maintainer is a person who is responsible to repair the computer problems and must check every computer one-by-one so as to classify the hardware faults. Usually a computer technician as they said will take from 10 minutes up to 5 hours on average 3 hours to detect and identify the causes of computer hardware fault depending on the know-how he/she has. This is the main reason why a computer technician needs a knowledge based system to help them in managing daily operation. Our aim is to designing a framework for personal computer hardware fault diagnosis and maintenance thereby assisting personal computer owners in dealing with their computer problems especially when the time is limited and human expert is not available. To this end, this study explores and answers the following research questions.

- ✓ What are the common computer hardware faults?

- ✓ What type of knowledge is required to design a framework which can assist experts in computer diagnosis and maintenance?
- ✓ How to acquire, model, represent, and design a framework for computer hardware faults?
- ✓ To what extent the performance of the prototype is accepted by the domain experts?

3. OBJECTIVE OF THE STUDY

The research has both general and specific objectives as stated below.

5.2 General Objective

The general objective of this research is to design a framework for personal computer hardware fault diagnosis and maintenance.

4.1 Specific Objectives

To achieve the general objective of this study, the following specific objectives are formulated:

- ✓ To conduct related literature review in the area of the available models and techniques.
- ✓ To identify personal computer hardware fault diagnosis and maintenance and provide a systematic and step-by-step analysis of the causes of the problems.
- ✓ To acquire tacit and explicit knowledge in personal computer hardware fault diagnosis and maintenance.
- ✓ To model and represent the acquired knowledge.
- ✓ To evaluate the performance of the system and conduct user acceptance testing.

4. METHODOLOGY OF THE STUDY

For the successful completion of this study, different global and local researches have been thoroughly reviewed starting from the beginning of the study until its completion. Journal articles, conference papers, manuals, reports and books are reviewed for achieving the research objective.

5.2 Research Design

This study follows design-science approach. The design-science paradigm has its roots in engineering and the sciences of the artificial. It is fundamentally a problem solving paradigm. It seeks to create innovations that define the ideas, practices, technical capabilities, and products through which the analysis, design, implementation, management, and use of information systems can be effectively and efficiently accomplished [5]. Design supports a problem solving paradigm that continuously shifts perspective between design processes and designed artifacts for the same complex problem. The design process is a sequence of expert activities that produces an innovative product (i.e., the design artifact). IT artifacts are broadly defined as constructs (vocabulary and symbols), models (abstractions and representations), methods (algorithms and practices), and instantiations (implemented and prototype systems) [5]. This research artifact is a framework for personal computer hardware fault diagnosis and maintenance.

4.1 Knowledge Acquisition Process

The knowledge acquisition phase requires a significant degree of interaction between the knowledge engineer and the experts [6]. During this phase, the knowledge engineer use techniques to elicit tacit knowledge from discipline experts. The process of knowledge acquisition in this research work includes some basic activities such as gathering the required knowledge, analyzing that knowledge, identifying important concepts focusing on causes and symptoms of personal computer hardware faults. In order to acquire required knowledge for this study both secondary and primary sources of knowledge are used. The techniques used to extract relevant knowledge from these sources are:

- ✓ Reviewing related documents and manuals
- ✓ interviewing domain experts

Reviewing Related Documents and Manuals

Document analysis involves gathering knowledge from existing documentations. Hence, document analysis has been carried out to acquire explicit knowledge which is found in various secondary sources of knowledge. Accordingly, different source books, Internet resources and computer maintenance and troubleshooting guide lines are reviewed and analyzed. As the result, relevant and technical knowledge were extracted and structured in a manner that suitable for knowledge modeling and finally knowledge representation.

Interviewing Domain Experts

Both structured and unstructured interviews were employed to elicit tacit knowledge from domain experts. Since one of the specific objectives of this research is extracting tacit knowledge which is embedded and personalized in experts mind. For this reason, three experts from ICT support staff and two experts from lab technicians from university of Gondar were selected purposely for interview. These experts were interviewed about computer hardware faults and the symptoms of these fault as well as solutions undertaken to control such faults. During face to face communication, the information obtained from experts has been recorded manually by using pen and paper sheet. After the interviews with the experts and thorough review of the related documents and manuals, the researcher summarized, which gives information about symptoms and the solution undertaken to control such faults of the computer hardware.

5.2 Case Representation, Indexing, Selection and Retrieval

For this research, the acquired cases are represented using one of the different case representation methods that are appropriate for the research. Among the different case representation methods, feature-value case representation method is used. Other case representation methods like relational database case representation, predicate based representation and soft computing case representation methods have their own advantages and disadvantages. But, for this study feature-value representation method is appropriate. The reason for representing cases using feature-value representation is that this approach supports nearest neighbor retrieval algorithm and it represents cases in an easy way [4] [10]. In addition to representation of cases, case indexing is another important issue in CBR systems to facilitate the retrieval of cases. In this research case indexes are first assign by knowledge engineer as case Id and in the retaining stage the system automatically generate starting from next to the last index value in the case based. Cases are selected and retrieved based on their similarity for the given new case query. There are different case retrieval algorithms that different CBR systems used. For this research nearest neighbor retrieval algorithm is used to measure the similarity of input case with

cases in the case base. Induction algorithm cannot deal with missing data so a wrong case may be retrieved or unknown, it may not retrieve a case at all [4].

5. DESIGNING THE FRAMEWORK OF PCHFD

The framework for personal computer hardware fault diagnosis (PCHFD) shown in figure 1 depicts how the knowledge developed and stored in the case base , how the algorism infer for the given problem and how the prototype works during personal computer hardware fault diagnosis. In this framework there are three modules knowledge development, architecture and prototype. These three modules are closely linked to one another and communicate with each other. The knowledge engineer gather raw computer cases based on the requirement gathering methods and then design case structure by selecting appropriate attributes and assign metadata for those selected attributes and then stored the cases structure in xml format. Next specify case structure and plaintext file path and generate connector, connector is also saved in xml format finally stored in general knowledge. As the new query is entered, the prototype of the system matches the new case to the solved case in the case base of the system by using similarity measurement. If relevant cases are found within the case base, then the prototype rank the relevant retrieved cases based on their global similarity. Next, the prototype proposes a solution. The proposed solution can be derived directly from a retrieved case that matches exactly or partially to the problem of the new case. But, using the proposed solutions directly may have a risk. Therefore, the user of the system should have made an adaptation by altering the differences between the proposed case and the new case. In addition to adaptation, case inconsistencies are revised if the retrieved case is not the same as the new case. Finally, the revised solution is retained in the case base for future problem solving using automatic indexing.

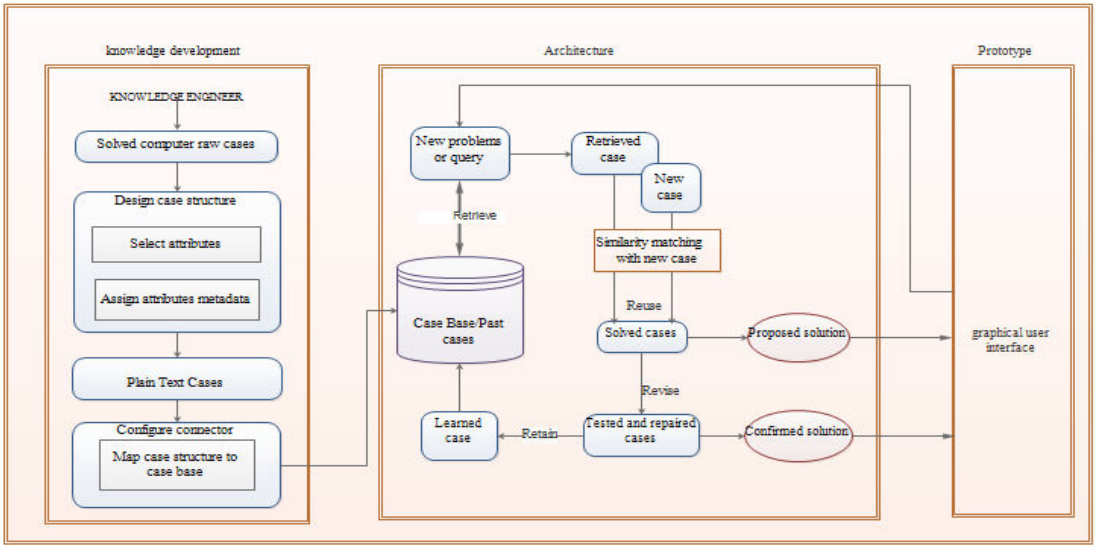

Figure.1. A Framework of PCHFD

5.1 Building the Case Base:

The researcher collects computer hardware fault cases from university of Gondar ICT support staff and lab technician. The acquired cases are used to build knowledge base for personal computer hardware fault diagnosis that is used to assist by offering decision support to computer hardware maintainer and individual computer users. All the acquired cases are stored as plaintext file in a feature-value representation format from the .csv (comma separate value) file format after preprocessing.

The case base is presented as a plaintext comprising of n columns representing case attributes (A1, A2, A3, …, An) and each m rows representing individual cases C ({C1, C2, C3, …,Cm}) each attribute has a sequence of possible k values associated to each column attribute A={V1, V2, V3, …,Vk}. The reason for representing cases using feature-value representation is that this approach supports nearest neighbor retrieval algorithm and it represents cases in an easy way [7].

Table.1. Sample Cases in the Case Base

Case Id	squealing or other loud noise	Nothing happens when I turn on the PC	PC freezes before the operating system starts loading,	PC randomly shuts itself off	ratcheting or tick tock sound	Cannot load Operating System Message	Hard Disk Fault message	drive drawer will not open
Case 1	true	false	false	true	true	false	false	false
Case 2	false	true	false	false	false	false	false	false
Case3	false	false	true	false	false	false	false	false
Case 4	true	false	false	true	false	false	false	false
Case 5	true	false	false	false	true	false	false	false
Case 6	false	false	false	false	false	true	true	false
Case 7	false	false	false	false	false	true	true	false
Case 8	false	false	false	false	false	false	false	true

The collections of cases are represented in the feature-value representation to make efficient retrieval process. This is done through case indexing process. Indexing refers to assigning indices to cases for retrieval and comparison of a query to the case base [8]. The index value for new cases will be generated by the system by increasing the number of existing cases. Index used for centralized representation, memory and the recovery of cases. The cases are restructured in order in the new case being placed at the end of the other cases as shown in figure3

Description of Case Attributes:

In jCOLIBRIcase structure define using manage case structure window. Add attributes in description of case structure and set properties of attributes or metadata of attributes. Metadata of attributes are weight of attribute, data type of attribute and similarity function. During configuration of case structures, jCOLIBRI creates codes automatically and saved in xml file format and used to manage tasks and methods. PCHFD prototype case base has 23 description attributes and 1 solution attributes. Solution attribute is used after finding best selected cases and the recommended diagnosis given to the fault.All case attributes are with data type Boolean, with assigned weight 1.0 because the importunateness of the attribute have not different means no more important attribute as compare to others and with local similarity of equal since the input value is true or false so the system give result when it gets exact match of true or false value. This values are used to configure properties and similarities of case structure.

Case Revision: In computer diagnosis adaptation is a commonly required task. Since this research main goal is developing personal computer hardware fault diagnosis system, adaptation is necessary. Initially the system load case bases at the PreCycle stage and then selects working cases from the case base and stores the cases in to current context at the retrieval stage. The next stage is reusing the cases that are loaded in the working memory. If there is no difference between a current case and the retrieved similar cases, null adaptation of solution can be possible. When the previous solution is not fully reasonable in the current problem, only few modifications are required to fit the current situation. This issue is a serious issue especially in personal computer hardware fault diagnosis because of the corresponding risks. Therefore, the adaptation stage requires domain expert knowledge about how differences in problems of previous case and the current situation are occurred. So, it is up to the domain experts to reuse the retrieved cases to solve the new case rather than the system by itself derives solution. Hence, the adaptation stage of PCHFD is left to the users of the system by comparing specified parameters of the retrieved and current case to modify the solution in a way that can fit to the problem at hand. In general, the adaptation process of PCHFD is successful as the case features of the previous and new case have similar or less inconsistency attribute values. On the other hand, no adaptation process can be performed as the attribute values of the previous and new cases have more dissimilar or totally different from the previous cases. However, often a direct application of an uncertain solution is impossible due to the corresponding risks, especially in computer diagnosis systems. Therefore, the adaptation has to be performed manually by a human domain expert as shown in the below snapshot.

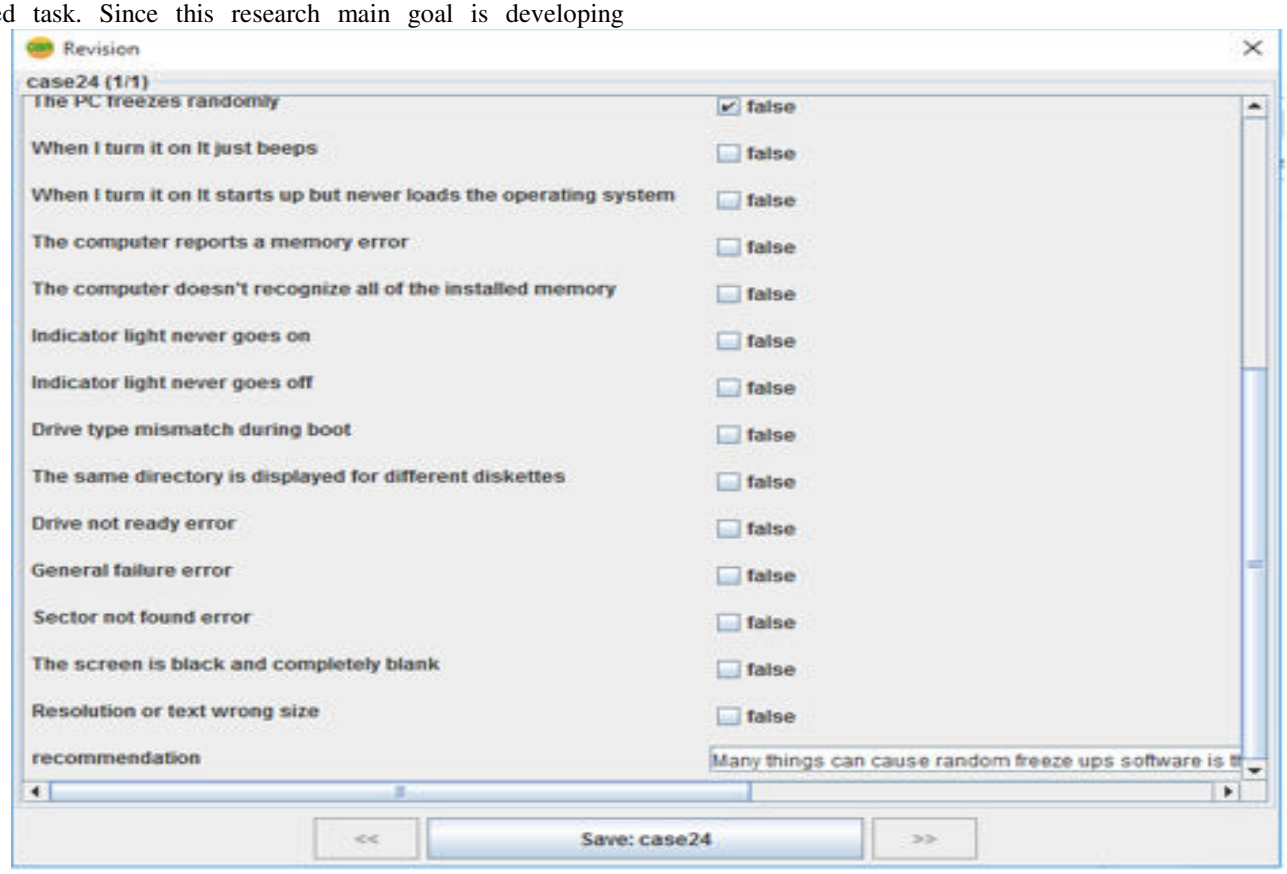

Figure .2. Depicts Revision Interface:

Case Retaining: The last cycle in PCHFD prototype development is case retaining, which is an important step in storing new cases which will use for future diagnosis. Especially, in personal computer hardware fault diagnosis, retaining cases over time is important because mostly the diagnosis using technicians tacit knowledge and personal experience.

Personal computer diagnosis CBR systems should be designed as life-long learning application. CBR systems in computer diagnosis should not be designed only to reuse past episodes with little modification instead retaining new cases for solving similar problems for the future is necessary because technology is a rapidly changing field from time to time, and computer practice guidelines are regularly updated. In this research, retaining cases after revision is possible by assigning case index. The system indicates the next case index next to the last index from stored cases and we can change manually as shown in the below snapshot

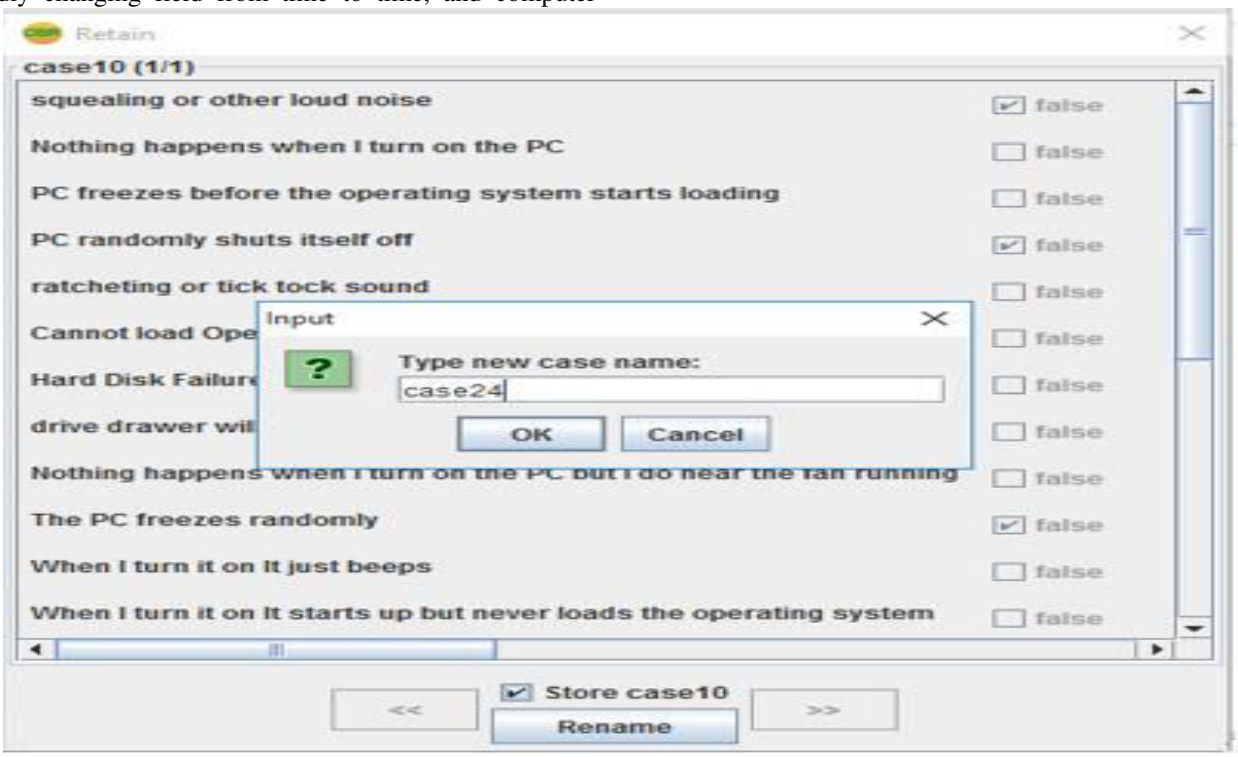

Figure.3. Case Retaining Dialog Box

6. EVALUATION OF THE PROTOTYPE

The statistical analysis evaluation uses 23 computer hardware fault cases that have been collected from university of Gondar ICT support staff and lab technicians. In this research, the effectiveness of the retrieval process of the PCHFD is measured by using recall and precision. According to McSherry [9], precision and recall are the commonly used measures of performance of the retrieval process in CBR. Recall is the ability of the retrieval system to retrieve all relevant cases to a given new problem (query) from the case base. On the other hand, precision is the proportion of retrieved cases that are relevant to a given query. The relevant personal computer hardware fault cases from the case base should be identifiedfor each test case to conduct the evaluation, test cases are given to the domain expert in order to assign possible relevant cases from the case base to each of the test cases. The domain expert uses the value of recommendation (solution) attributes of the computer hardware fault case as the main concept to assign the relevant case to the test cases. After the identification of the relevant cases to the test cases by the domain expert, precision and recall are calculated as follow by using the computational equation.

$$\text{Recall} = \frac{\text{Number of relevant cases retrieved}}{Total\ number\ of\ relevant\ cases}$$

$$\text{Precision} = \frac{Number\ of\ relevant\ cases\ retrieved}{Total\ number\ of\ cases\ retrieved}$$

Table 2: Relevant Cases Assigned by the Domain Expert for Sample Test Cases

Test Case	Relevant cases from the case base
Case1	Case4, Case8 Case10, Case14
Case4	Case1, Case9, Case14 ,Case16
Case6	Case 2 Case7, Case14, Case15
Case11	Case3, Case12, Case13
Case14	Case1,Case4, Case6, Case11
Case15	Case6, Case7, Case5, Case16, Case18
Case18	Case15, Case16, Case19,Case21

Both recall and precision results are above average which is a hopeful result. The average recall and precision results 79% and 74% respectively which is also a promising result. The reasons that the prototype couldn‘t achieve 100% retrieval and reuse performance could be due to the data and the algorithm used to develop the prototype. The Nearest Neighbor algorithm, which is used to develop the retrieval process of the prototype, uses distance to compute the similarity between the query and cases

by representing the cases in N dimension vector. However the recommendation for the computer hardware fault cases doesn't have clear boundaries as it has subjectivity and depends on the experience of the domain experts. In addition, the importance value that are assigned to the attributes of the case structure are done manually with the help of the domain experts, as there is no research that is conducted for the importance value of the attributes in personal computer hardware fault system. This could affect the result of the retrieval and reuse performance of the prototype. The performance of the retrieval process and reuse process of the prototype can be improve, if way of mechanism that assigns an importance value to the attribute is integrated to the prototype.

7. CONCLUSION

This study was conducted for designing a framework for personal computer hardware fault diagnosisusing case based reasoning that could help the domain experts in managing computer hardware case in terms of retrieving similar cases to the query from the case base, adapting the retrieved case for use, revising the adapted solutions and retaining the modified case for future use to solve the current problem. The computer hardware fault cases were represented in an attribute-value vector to build a plain text file for case structure and connector in CBR. The represented plain text file was indexed or mapped with the appropriate selected attributes. The four CBR tasks were then configured using the mapped case structure and connector to build a case base for managing the cases using four "Re's" (Retrieve, Reuse, Retain and Revise) of CBR tasks in general. When measuring the performance of the system, promising results are found. The standard effectiveness measures of information retrieval, such as (recall and precision) are used to measure the retrieval performance of PCHFD. Using these evaluation methods, the system achieved 79% recall and 74% precision which is a hopeful result to apply CBR in the personal computer hardware fault diagnosis. In addition the performance of the system is evaluated by the potential users of the system and achieved 88% user acceptance In general, the study achieves its objective by designing the framework with promising performance and user acceptance, and demonstrating case-based reasoning approach in designing knowledge based system for personal computer hardware fault diagnosis. The major challenge in this research constructing cases and assign attribute values both done manually with the help of domain experts. The performance of the retrieval process and reuse process can be improve if it is done with the machine learning algorithms automatically.

8. FUTURE RESEARCH DIRECTION

The study attempts to come up with designing a framework for personal computer hardware fault diagnosis and maintenance. However, there are problem areas that need further investigation and the researcher recommends the following issues as a future research direction based on this study.

- ✓ In this study we consider only text-based cases for designing a framework. However there are multimedia that can support during computer hardware fault analysis. Hence we recommend for further research that integrate multimedia with the case-based reasoning.
- ✓ In this research, the importance values of the attributes are assigned manually with the help of domain experts. The performance of the retrieval process and reuse process can be improved if it is done with the machine learning algorithms automatically. A possible future work direction can be to investigate and integrate machine learning algorithm for assigning weight for the attributes.

9. ACKNOWLEDGEMENT

First and foremost I would like to thank God and Holy Mother who made all things possible, and granted me success in my thesis work and entire journey. I am heartily thankful to my advisor, Dr.Million Meshesha, who patiently advised me with scholar guidance and constructive comments on my work throughout this endeavor, without him I could not reach to this stage. I would also like to acknowledge and extend my heartfelt gratitude to ICT support staff and lab technicians in university of Gondar for their unconditional support during the knowledge acquisition. My deep appreciation and thanks extended toall my friends for their support.

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BIOGRAPHY

Mulugeta Shitie, received the BSC degree (with distinction) in Information system from wollo university,Kobolcha Institute of Technology(KIOT),Ethiopian 2013 and MSC in Information technology from university of Gondar.(phone No:- +251 918 17553, email:- mshitie@gmail.com)

Million Meshesha ….Doctor please put your biography here