Global Scientific JOURNALS

GSJ: Volume 5, Issue 7, July 2017, Online: ISSN 2320-9186
www.globalscientificjournal.com

FRAMEWORK FOR DESIGN OF ARTIFICIAL INTELLIGENCE EXPERT SYSTEM FOR VHF OMNI–DIRECTIONAL RANGE (VOR)-DME AND LOCALIZER FAULT DETECTOR AND TROUBLESHOOTING

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ABSTRACT
When VOR/DME and LOC/DME breaks down, it is often difficult to trace the cause (s) of such malfunctions with respect to identified symptoms. Frequently, some of these faults are so minor such that it is needless undergoing the rigors and time consuming effort of finding maintenance experts. Presently, there is no readily available Expert System to assists non-expert to easily identify and rectify minor problems of the VOR/DME and LOC/DME especially when the maintenance experts are not handy. The aim of this research project therefore, is to design a knowledge-based Expert System to assist non-experts for tracing and rectification of several known faults commonly developed by VOR/DME and LOC/DME. The research work adopted the Object Oriented Analysis and Design (OOAD) approach in the design of the system. The knowledge acquisition process was carried out through interview with VOR/DME and LOC/DME engineers and other stakeholders. Unified Modeling Language (UML) which is a graphical language was used to specify the behavior of the system. Java programming language was used to develop and implement the knowledge-base system using the production rule. MySQL was used as the database engine to organize the expert knowledge. The Mobile Based Intelligence Expert System developed was tested using several test data. Several test method such as component/unit testing and integrated testing were employed to test the efficiency and capability of the system.

Keywords: Localizer, VOR-DME, LOC/DME, Expert System, Fault Management, AI

Introduction

Aircraft performance is achieved by controlling the aircraft attitude and power. Aircraft attitude is the relationship of its longitudinal and lateral axes to the Earth's horizon. An aircraft is flown in instrument flight by controlling the attitude and power as necessary to produce the desired performance. This is called the "control and performance concept" of attitude instrument flying and can be applied to any basic instrument maneuver (AFMAN11-217V1, 2010)[1]. These instruments are classified into three: the control instruments, the performance instruments and the navigation instruments. The VOR and DME are belonging to the class of Navigation Instruments which indicate the position of the aircraft in relation to a selected navigation facility or fix. Distance measuring equipment, frequently called DME is one of the most valuable pieces of avionics in the aircraft. The main purpose of the DME is to display your distance from a VORTAC, VOR-DME, or localizer[2]. The VOR-DME (very high frequency Omni-directional Radio range/Distance Measuring Equipment) and LOC/DME (Localizer/Distance Measuring Equipment) are radio navigation aids among other short range navigation aids which are recommended by the ICAO (International Civil Aviation Organization) and introduced internationally for short and medium range aircraft guidance. The VOR provide aircraft radial with respect to a Ground Station, while the DME provide distance between aircraft and Ground Station. VOR and DME are both located at the ground and also at aircraft. The operation of VOR & LOC is based on the measurement of the phase angle of two 30H_z signals radiated by the station. One signal (Reference Signal) is radiated with the same phase in all directions. For the second 30H_z signal (Variable Signal), the phase relationship relative to the first signal changes as a function of the azimuth. The electric phase angle measured in the airborne receiver corresponds to the azimuth angle. DME operation utilizes paired pulses transmitted from the aircraft to a ground station at a specific spacing. The ground station then transmits paired pulses back to the aircraft at the same pulse spacing but on a different frequency. The time required for the round trip of this signal exchange is measured in the airborne DME unit and is displayed to the pilot as a distance in nautical miles from the aircraft to the ground station. The VOR provides the pilot with the following information via the VOR airborne receiver;

i. **The azimuth indication of the aircraft's position relative to the ground beacon that is the angle between the lines of magnetic North and the direction ground beacon to aircraft.**

ii. The bearing which indicates whether the aircraft is flying to the left or right of the preselected course (position line) or whether it is exactly on it.

iii. The "from/to" indication which shows whether the aircraft is flying toward the VOR or LOC beacon or away from it. The VOR or LOC is prone to undergo wear and tear like other machines and so requires repairs and maintenance.

Voice communication is possible on VOR, ILS, and ADF frequencies. The only positive method of identifying a station is by its Morse code identifier either aurally or alphanumeric display or (for VORs) the recorded automatic voice identification, indicated by the word—VOR‖ following the station name. The centrality of these equipments to air flight implies that availability of expert VOR/DME engineers is inevitable. When VOR/DME and LOC/DME breaks down, it is often difficult to trace the cause(s) of such malfunctions with respect to identified symptoms, especially for non-experts. In the event of unanticipated circumstance necessitating the absence of the engineer, can a pilot or a crew or any other flight official attempt diagnosis and effect repairs to save lives? Most times, some of these faults are so minor (though damaging) such that it is needless undergoing the rigors and time consuming effort of looking for experts. Presently, there are no common and readily available Intelligent Expert Systems to assist non-expert to identify and rectify problems (minor or major) of the VOR/DME and LOC/DME especially when the maintenance experts are not handy for any reason.

Fault management has conventionally been defined as the detection, diagnosis and correction of a fault or problem. Typically, the system is monitored to enable automatic detection[3]. Identifying a problem is a very difficult task because of complexity of the VOR/DME and Localizer and the constant change. The VOR systems are functionally complex as a whole, and additional complexity is introduced through the interactions of its different components. Diagnoses of such complex system require the services of an expert with some years of experience in the domain. Since human VOR/DME experts are scares, and as human, have limited life span, there is need for an intelligent system to complement the human experts. Artificial Intelligence is an incontrovertible innovation that can address and handle this. Artificial Intelligence is the branch of computer science concerned with making computers behave like humans. It is the study and design of intelligent agents, where an intelligent agent is a system that perceives its environment and takes actions which maximize its chances of success. John McCarthy, who coined the term in 1956, defines it as

"the science and engineering of making intelligent machines, especially intelligent computer programs. Expert system is a branch of AI which is concern with the design of intelligent system. It is a computer program that is designed to imitate the decision-making ability of a decision maker in a particular narrow field of expert knowledge or skill. It may monitor, detect faults, isolate faults, give advice, document, assist, etc.

2.0 Review of Related Literature

Edward Feigenbaum (1997)[4] said that the key insight of early expert systems was that "Intelligent systems derive their power from the knowledge they possess rather than from the specific formalisms and influence schemes they use". Although, in retrospect, this seems a rather straightforward insight, it was a significant step forward at the time. Until then, research had been focused on attempts to develop very general-purpose problem solvers such as those described [5].

Expert systems were introduced by the Stanford Heuristic Programming project led by Feigenbaum, who is sometimes referred to as the "Father of Expert Systems". The Stanford researchers tried to identify domains where expertise was highly valued and complex, such as diagnosing infectious diseases (MYCIN) and identifying unknown organic molecules (Dendral). In addition to Feigenbaum key early contributors were Edward Shortliffe, Bruce Buchanan, and Randall Davis. Expert systems were among the first truly successful forms of Artificial Intelligence software (Badiru & Ibidapo-obe, 1998)[6].

Research on expert systems was also active in France. In the U.S. the focus tended to be on rule-based systems, first on systems hard coded on top of LISP programming environments and then on expert system shells developed by vendors such as Intellicorp. In the 1980s, expert systems proliferated. Universities offered expert system courses and two thirds of the Fortune 1000 companies applied the technology in daily business activities. Interest was international with the Fifth generation computer systems project in Japan and increased research funding in Europe (Lugar & Stubblefield, 2004)[7].

In the 1990s and beyond the term "expert system" and the idea of standalone A.I. system mostly dropped from the Information Technology lexicon. But as I.T. professionals grasped concepts such as rule engines, such tools migrated from standalone tools for the development of special purpose "expert" systems to one more tool that an I.T. professional has at their disposal. Many of the leading major business application suite vendors such as SAP, Siebel, and Oracle

Integrated expert system capabilities into their suite of products as a way of specifying business logic. Rule engines are no longer simply for defining the rules an expert would use but for any type of complex, volatile, and critical business logic. They often go hand in hand with business process automation and integration environments (Edmunds, 1988)[8].

Expert systems have developed from a branch of computer science known as Artificial Intelligence (A.I.). Artificial Intelligence is primarily concerned with knowledge representation, problem solving, robotics, learning and the development of computers that can speak and understand human-like language (Townsend, 1987)[9]. According to him, expert systems are computer programs designed to mimic the thought and reasoning processes of a human expert.

Expert systems can be developed for many kinds of applications involving control, planning, prediction, diagnosis and interpretation (Edmunds, 1988). However, diagnosis still remains the primary application of expert systems, particularly for personal computers [9]. They are used in applications where the procedures or algorithms for the problem do not exist or are poorly defined by good rules of thumb or heuristics are available. In addition, expert systems are rapidly being accepted for use by the non-expert to solve problems when human expertise is expensive, untimely and unavailable.

Expert systems attempt to emulate how human experts solve problems, mostly by the manipulations symbols instead of numbers. Whereas conventional algorithm programming replaced most of the sophisticated, analytical work of engineers, expert systems are especially suitable for the no-less important tasks of the ill-structured and less-deterministic parts of planning and design (Basri, 1999)[10].

Furthermore, expert systems have been applied in many ways and various fields to make humans' lives simpler and easier. Example of areas of application include, expert systems technology in the domain of environmental management, in the domain of engineering, domain of agriculture (horticulture), domain of geology and chemistry, domain of medicine, etc. [10].

In the domain of engineering, expert systems have been developed for car maintenance and troubleshooting; this system was designed to help those who are in need of guides to deal with their car's problems [11]. Nevertheless an

expert system for the repairs and maintenance of VOR/DME and LOC/DME is presently being carried out.

According to Markham (2001)[12], expert systems are beneficial as teaching tools because they are equipped with unique features which allow users to ask questions on how, why and what format. Besides, an expert system is able to give reasons towards the given answers.

Possibly the largest obstacle in developing expert systems is extracting the knowledge from the human expert and transferring this knowledge into computer codes. For this reason, the process of constructing an expert system is known as knowledge engineering, and the system builder is referred to as the knowledge engineer[4].

Expert system developments consist of 3 phrases: Knowledge Acquisition, Knowledge Representation and Testing [13]. The knowledge acquisition is a time-consuming process in which the knowledge engineer works alongside the participating expert and extracts, structures and organizes the knowledge to be represented in the expert system [14]. Knowledge representation occurs after the domain has been identified; knowledge acquired from a participating expert, a model for representing the knowledge must be developed [9]. Testing therefore occurs when the knowledge engineer and the expert are satisfied that the expert system has been completed.

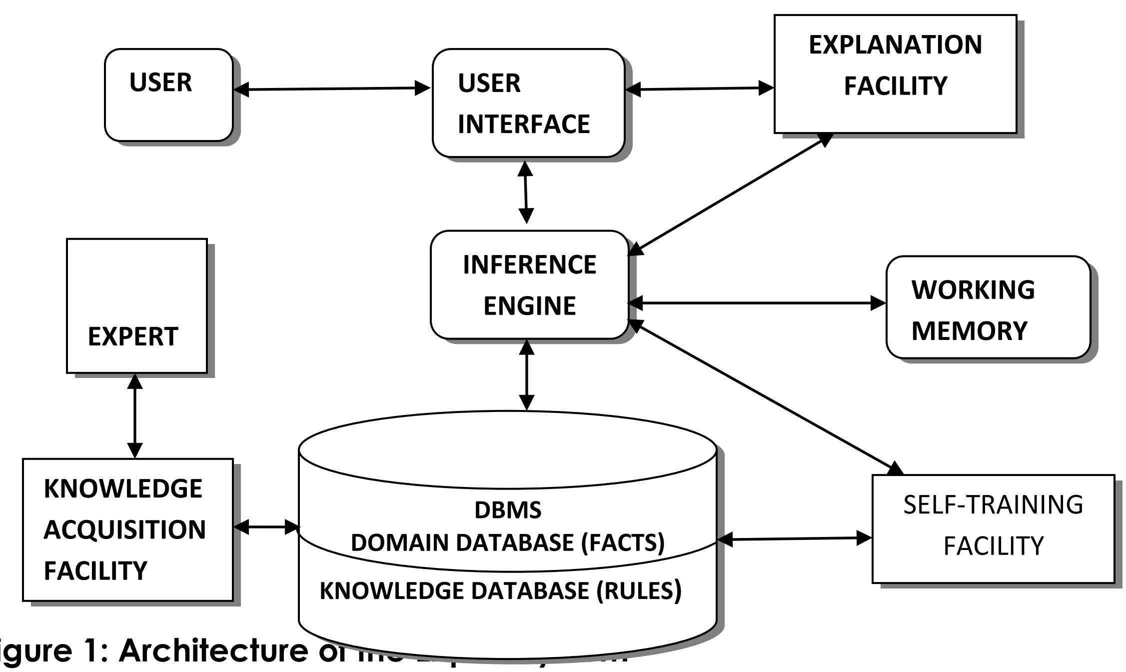


Figure 1: Architecture o...

3.0 Design and methodology

The proposed system was designed using the Object-oriented design approached. The design would adopt the use of modern modeling language, the Unified Modeling Language (UML). The UML is effectively a public, nonproprietary language that leans towards object oriented software development. It is a graphical modeling language that provides us with syntax for describing the major elements (called *object* in the UML) of software systems. The development will be carried out using the waterfall process model, which prescribes that each phase must be completed before the next stage can commence. The reason for proposing the waterfall model is because the waterfall model is easy to understand and simple to manage. The development of the system shall involve seven stages: (1) Requirement definition (investigation) (2) Analysis (3) Software design (4) Software coding (5) Software testing (6) Installation and conversion (7) Operation and maintenance. The study adopted the hybrid of SSADM and Object-oriented Analysis and Design methodology.

3.1 The Knowledge Acquisition

Acquisition of field knowledge is a major problem in the development of an expert system. Every expert system program requires an evaluation of the existing data and information that form the knowledge base for the exact problem. The method of knowledge acquisition in this system involved direct interview with VOR/DME experts and technicians. Information will also be sourced from books, journals, magazines, documentations, and articles related to VOR/DME and Localizer. Our task shall further include decomposition of the main field problem, integration of different data, use of different sources of knowledge, combining of doubtful information, organization and formulation of extracted knowledge.

3.2 The Knowledge Presentation:

Knowledge has different forms, it can be certain or uncertain, structured or unrelated. It can be found in formulas, tables, statements or well-established traditional practices. Because of efficiency of storage, consistency and naturalism of representation, production rule was used to represent the knowledge acquired in this study using Java programming language.

3.3 Functional Design:

The design of the expert system involves:

1. **Knowledge base design**
2. **Data base design**
3. **Design of an inference engine**
4. **Design of user interface.**

3.4 Design Details

1. **Knowledge Base: The knowledge base of the AI expert system stores the extensive knowledge that would were gathered from experts, engineers, journals, historical data and specialize books in the form of production rules, which contains the IF THEN rules.**

2. **Data Base Design:**

The data gathered would be put in the data base of the application. The data base table of the expert system would have three fields namely: problem, problem category and problem solution. The database will be designed using My SQL server.

3. **Inference engine:**

The inference engine provides the system control. It would match facts in the working memory against rules in the rule base, and it will determine which rules are applicable according to the reasoning method adopted by the engine.

4. **Graphical User Interface:**

   The graphical user interface of the system comprises of

   a. **User interface and**
   b. **Working memory**

a. User Interface:

This allows users to consult the expert system in a user friendly manner for decision support.

b. Working Memory:

The working memory contains the information that the system has received about the problem at hand. In addition, any information the expert system derives about the problem is also stored in the working memory. The working memory was designed to allow experts to update information in a user friendly

manner. The working memory of the system will be developed using Java netbeans technology.

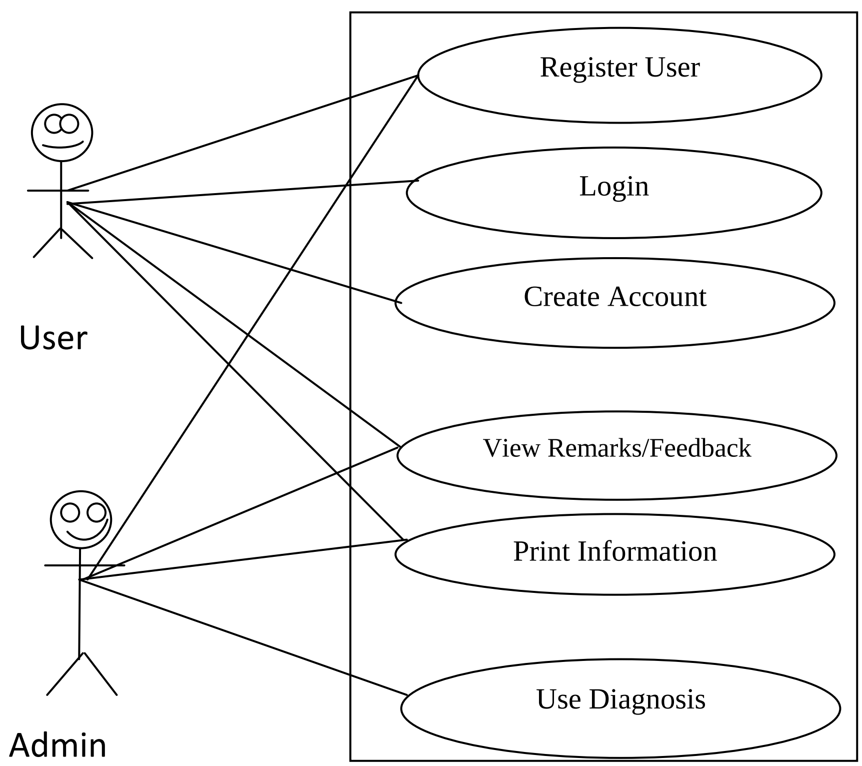
Choice of Programming language Tools

The choice language tools intended for adoption in the development of the proposed system include Java, due to its portability, object-oriented natured, garbage collection,, large libraries of classes and interfaces and its multithreading ability. Others are Java SDK (the Java software development kit), MySQL Server since it an open source relational database management system (RDBMS), and Aglet APIs.

System Design

Use-Case Diagram

The use-case diagram which is a scenario – based technique for requirements elicitation identifies the types of interactions and the actors (person) involved. It further describes what a system does from the stand point of an external observer and shows the tasks or functions a given user can perform with respect to the system[15]. The Use-Case diagram for the VOR-DME and Localizer is presented below:-



Activity Diagram

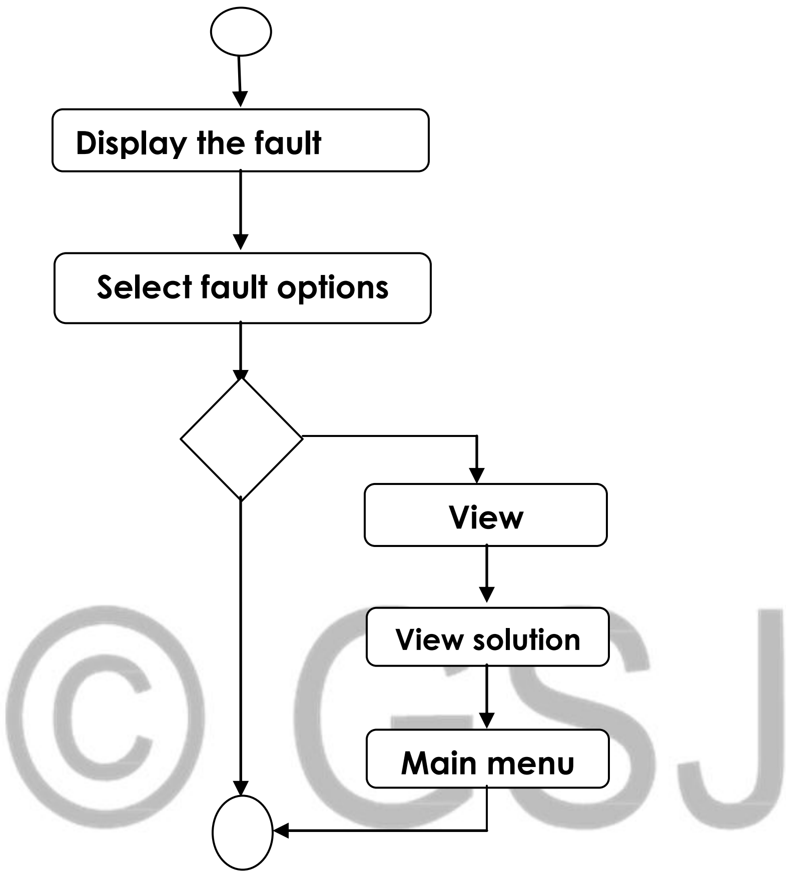


Figure 3: Activity Diagram for the Knowledge Engineer

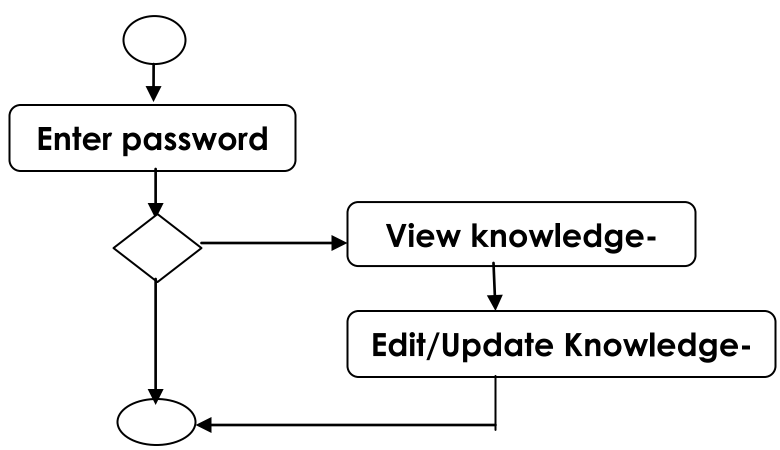


Figure 4: Activity Diagram for the Operator

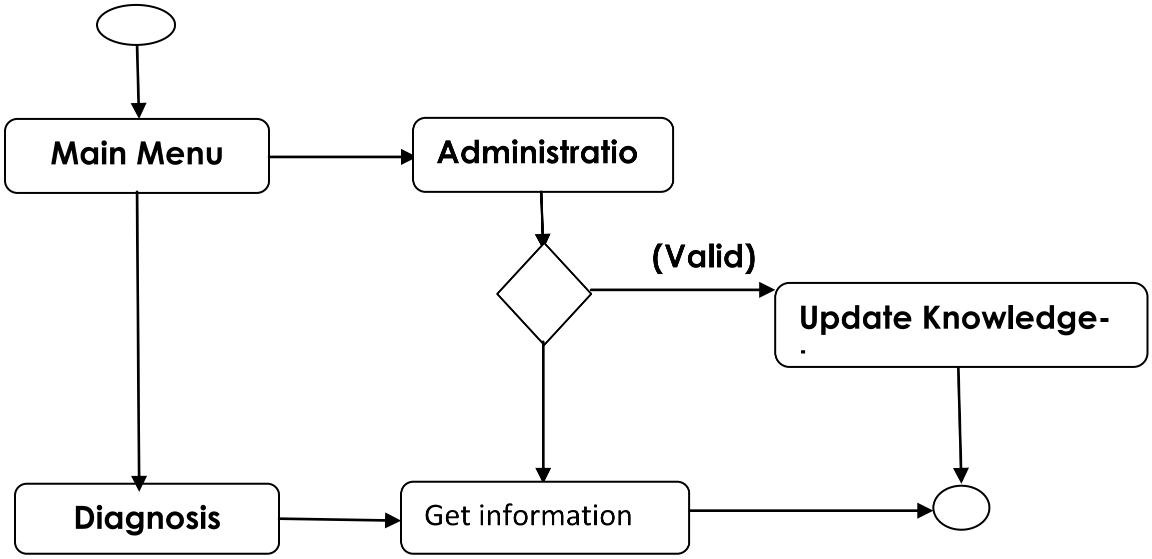


Figure 5: Activity Diagram for the Expert System

Program Specification

Program to diagnose and trouble-shoot faults
Begin
Display program main menu
If selection = perform diagnosis then
    Display fault input form
        Specify the fault
If selection = found
    Display reason for fault occurrence
    Display the diagnosis information report
Else
    If selection = print report then
    Print the report on paper Else
    If selection = Not found
    Display select an option
Else if selection = Exit then
    Terminate the application
End if
End.

System Controls

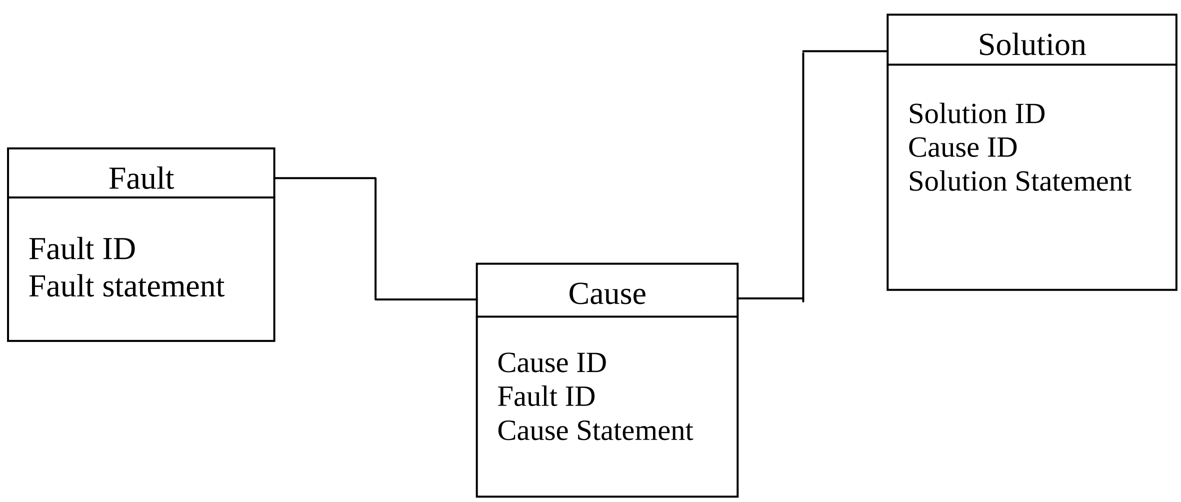
System control as one of the requirement to build a system is the ability to maintain system integrity such as data integrity and confidentiality through the incorporation of certain features into the system. This system provides the following system controls:

<u>Input Validation:</u> Security was built into the system using input mechanism to ensure that inputs are in required formats. The system filters and validates inputs by providing checkboxes in the fault input form; these checkboxes ensure that users enter data necessary for the system.

<u>Access Control:</u> A login authentication that gives users access to the menu page (the various functions provided by the system). A user who intends to access this application must provide the login details which include a user unique username and a password.

Structure of the Knowledge-Base

The structure of a knowledge-base shows the various tables that make up the knowledge base [16][17]. The knowledge-base for the proposed system consists of three tables namely: Fault Table, Cause Table and solution table. The structure of the knowledge base is as shown below:



3.4 Database Design

User Table

S/n	Field	Data_type	Null	Primary_key	Foreign_key
1	User_id	Int	No	No	No
2	Surname	Varchar	No	No	No
3	First name	Varchar	No	No	No
4	Middle name	Varchar	No	No	No
5	Address	Varchar	No	No	No
6	Staff_id	Int	No	P.k	F.k
7	State	Varchar	No	No	No
8	Nationality	Varchar	No	No	No
9	Level	Int	No	No	No

Administrator Table

S/n	Field	Data_type	Null	Primary_key	Foreign_key
1	Admin-id	Int	No	P.k	No
2	Surname	Varchar	No	No	No
3	First_name	Varchar	No	No	No
4	Middle_name	Varchar	No	No	No
5	Address	Varchar	No	No	No
6	Staff_id	Int	No	No	F.k
7	State	Varchar	No	No	No
8	Nationality	Varchar	No	No	No
9	Level	Int	No	No	No

Results

Interfaces of the Expert System Prototype

Figure 6: Program Login Page

Figure 7: Diagnosis Dialogue Interface for Expert System – User Interaction

Figure 8: Inference Engine Decision Interface that provide response to User's Query

Conclusion:

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