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An Expert System in Quality Management System Documents Management and Internal Quality Audits

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Abstract: Now-a-days, many organizations have tried to obtain ISO 9001:2000 certification. This International Standard promotes the adoption of a process approach in order to enhance customer satisfaction by meeting customer requirements. This process approach is used in the time of developing, implementing and improving the effectiveness of a Quality Management System (QMS). This study discusses the development of an expert system for the QMS document management and internal quality audits. The costly and time consuming steps to attain the ISO 9001:2000 status, which at the present moment is carried out by quality auditors, has inspired us to develop an expert system that will be able to mimic the role of the auditors. This expert system will be useful for the initial stage of the certification process, the document management or termed as adequacy auditing stage. It is believed that, by using the system, the process of the ISO Certification could speed up. Adding to that, the system is capable of providing suggestions and advices just like a consultant would. The software languages used are AMZI! Prolog and Microsoft Visual Basic.

Key words: QMS, ISO 9001:2000, expert system, internal audits, document management, AMZI! Prolog

INTRODUCTION

This study discusses the development of an expert system for the QMS document management and internal quality auditing. The system will focus on a selected department in University Tenaga Nasional (UNITEN). The chosen department is the Computer Science and Information Technology of the College of Engineering. The system will be able to audit the department based on several procedures and other selected documents. The system can later on be used for other Institutions of Higher Learning.

In the competitive business market, the need for an organization to be ISO Certified has increased. The certification brings numerous advantages to an organization. The fee of this process is rather hefty. In average, adequacy auditing takes two days to complete and involves all the organization's employees in charge of the preparation of the documents. This procedure absorbs labor time and organization costs. The costly and time consuming steps to attain the ISO 9001:2000 status, which at the present moment is carried out by quality auditors, has inspired us to develop an expert system that will be able to mimic the role of the auditors.

The objectives for the development of the expert system are two-fold: Firstly, this expert system will be useful for the initial stage of the certification process, the document management or termed adequacy auditing stage. Secondly, to perform internal quality audit with the consistency of information, provide consistent advice to the users, as well as to produce a system that is flexible to use at any time, i.e. it could acts as a first party auditor. It is believed that, by using the system, the process of the ISO Certification could be speed up. In addition, the system is capable of providing suggestions and advices just like a consultant would. As a result, it is a big advantage to the university in saving the running cost to hire ISO Internal Quality Auditor at initial stage of the certification process.

The questions will relate to the criteria of the adequacy audit for the ISO 9001:2000 process. In designing the expert system, the knowledge acquisition method is used in order to obtain the expert knowledge. Next, the selection of knowledge representation scheme is carried out. Elicited knowledge will be organized in such a way that a computer inferencing program will be able to access them whenever needed and to draw conclusions.

In a nutshell, the developed prototype will be able to provide assistance to an organization with expertise similar to the domain expert, such as a SIRIM consultant and quality auditors, which will be less in cost and consumes minimal time as oppose to the current method.

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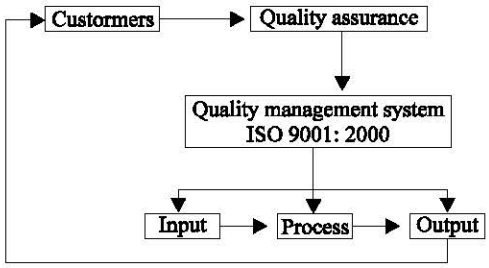

Fig. 1: The relationship between quality assurance and QMS

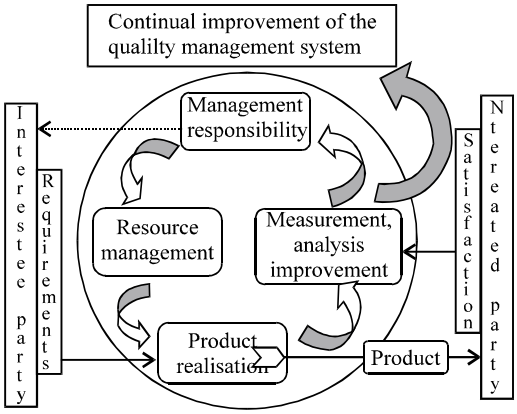

Fig. 2: The quality management system process model

It is hoped that the work will invite further research and development of expert systems development for other aspects of a QMS.

Domain overview

Introduction to ISO 9001:2000: ISO 9001:2000 is an international standard on Quality Management System (QMS) requirements necessary for Quality Assurance in an organization. It sets out requirements suitable for an organization to demonstrate its Quality Assurance capability and for the assessment of that capability by an audit or review process. The standard seeks to achieve excellence through continual improvement of the performance of an organization. This could be achieved by developing a Quality Management System based on the 'Process-based approach'[1]. To function effectively, an organization needs to identify and manage numerous inter-linked processes. An output from a certain process will directly be from the input into the next processes. This interaction within the organization is referred to as the 'process approach'. Based on this approach, ISO 9001:2000 is structurally developed under 5 main topics which are:

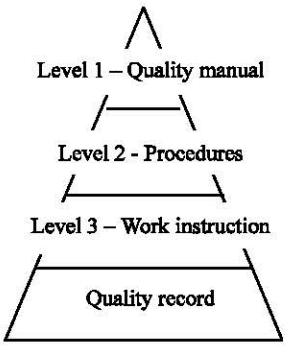

Fig. 3: Documentation structure

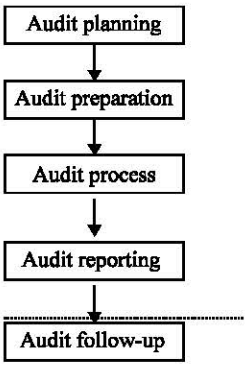

Fig. 4: Auditing flow

- Quality Management System (QMS)
- Management Responsibility
- Resource Management
- Process Management
- Measurement and Analysis Improvement

These standards provide a framework for quality systems development in all types of industries, including service organizations. The table below briefly shows the essential features of the ISO 9001 Quality Assurance Standards. The association of Quality Management System, Quality Assurance and ISO 9001 is illustrated in Fig. 1. The organization will keep maintaining its quality in products and services by conforming to the ISO 9001 requirements. The Quality Assurance will make certain that comments and suggestions of customers are heard and corrective actions are made available for further improvement of the organization.

Quality management system (QMS): To further understand what Quality Management System is, 'quality' must be defined. Based on ISO, this term refers to the ability of a set of inherent characteristics of a product/system/process, to fulfill requirements of customers and other interested parties. Generally, quality

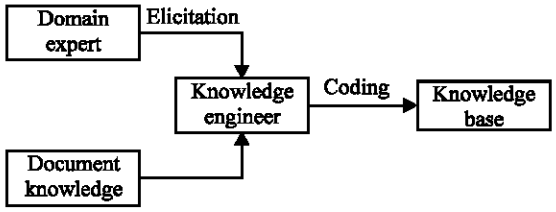

Fig. 5: Manual method of knowledge acquisition

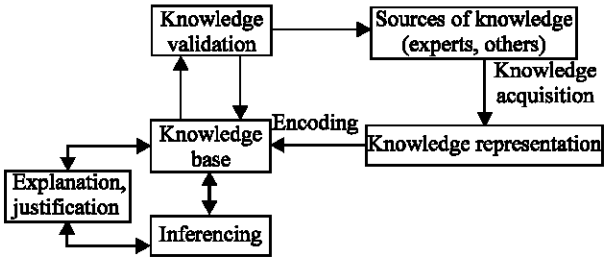

Fig. 6: System architecture

in a product is when customers are completely satisfied with it. This is achieved by meeting the customer's requirements and expectations of the product. Quality is critical in the world market since there are so many companies working hard to offer products which are of best value for the customers' money.

Any organization that wishes to survive in the market needs to offer their products at a practical price at which the customers are willing to pay. Hence, the organization must implement and maintain a management system that is designed to constantly improve their performance, to provide best value for money products. This is where the QMS process model (Fig. 2) is applied to achieving this goal. The term Quality Management System is then defined as a system to establish quality policy and quality objectives and achieving these determined objectives in a certain period of time. The elements involved are people, processes and procedures.

Documentation objective and structure: ISO 9000 require that an organization to establish procedures for controlling activities and that those procedures should be documented where required by the standard and where necessary to achieve adequate control. The components in documentation comprises of the different category of documents. These categories are termed as 'levels'. There are 3 levels of documents (Fig. 3).

Internal quality audit: Internal Quality Audit is systematic investigations by specially trained auditors into the operation of an organization's quality system. Internal Quality Audit provides objective evidence that [2]:

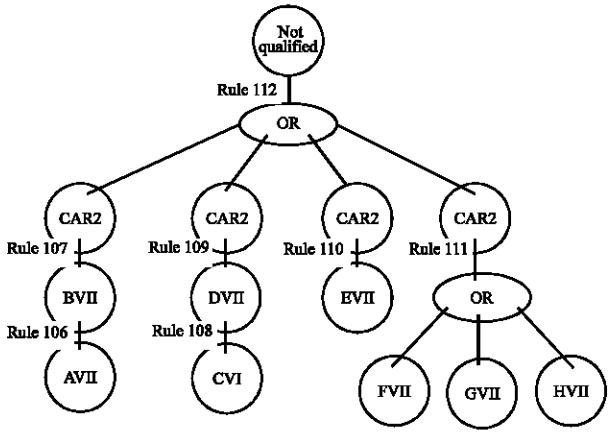

Fig. 7: Not qualified for ISO 9001:2000 standard

Not qualified	-	Not qualified for ISO 9001: 2000 standard
CAR23	-	Issue corrective action request 23
CAR24	-	Issue corrective action request 24
CAR25	-	Issue corrective action request 25
CAR26	-	Issue corrective action request 26
AVII	-	Examination paper solutions and marking schemes is prepared by lecturer
BVII	-	Responsibility is incorrect
CVI	-	Answer for examination questions
DVII	-	Marks allocation are not moderated by second examiner or external examiner
EVII	-	No marks for each subsection
FVII	-	Marks for each subsection
GVII	-	Marks not shown in the right side
HVII	-	Total marks not shown in the bottom-right side

- The organization's Quality System, as defined by its Quality System Framework Documentation, satisfies the requirements of the ISO 9001:2000 Standard.
- The Quality System Framework Documentation is being fully implemented throughout the organization.
- The Quality System Documentation is effective in producing a quality assured product or in providing a quality assured service.
- The Quality System Documentation and the organization's operations are in accord with the organizations own Quality Policy statement.

There are three types of audit, namely:

- First Party-audit of the organization by its management.
- Second Party-audit of the vendor by the organization for award of contact.
- Third Party-audit by independent organization for certification or accreditation.

Fig. 8: The main page of the system

This prototype covers only first party audit and the auditing flow process is shown in Fig. 4.

System overview

What is an expert system?: An expert system is an artificial intelligence application that uses a knowledge base of human expertise to aid in solving problems. The degree of problem solving is based on the quality of the data and rules obtained from the human expert. Expert systems are designed to perform at a human expert level. The expert system derives its answers by running the knowledge base through an inference engine, a software program that interacts with the user and processes the results from the rules and data in the knowledge base.

Why expert system for internal quality audit and documents management?: Expert system is chosen because expert system needs to draw the conclusion whether the area being audit is qualified for ISO 9001:2000 Standard. Conventional systems that use conventional programming such as Structured Query Language (SQL) is not suitable for internal auditing. The conventional programming only can retrieve the data, but cannot draw the conclusion and give the advice to the user. Furthermore, user can use natural language to communicate with the system, rather than remember the command and the syntax to retrieve the data. Moreover, expert system uses heuristic programming to search for the best answer it can give based on the knowledge it has. The knowledge engineer can easily insert new facts to the knowledge base in the expert system.

This expert system can run on Windows platform and the computer should install AMZI! Prolog + Logic Server and Microsoft Visual Basic 6.0.

System output: The expert system will present questions to measure an organization's qualification for the ISO 9001

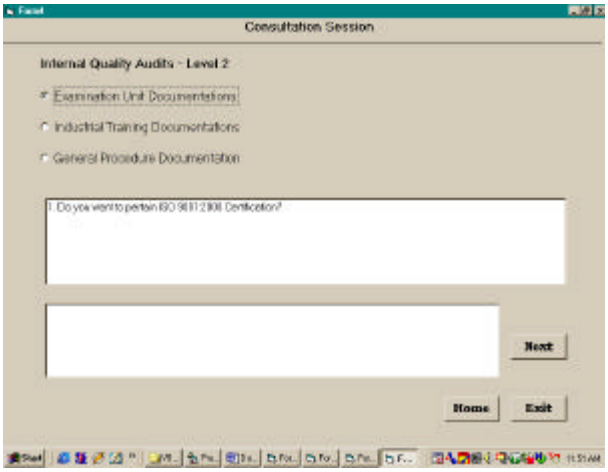

Fig. 9: A view of the internal audit process

Certification. The system will be able to determine the status of the organization based on the document adequacy and internal audit status.

In document adequacy check, there are three status involved which are as listed below:

- The Quality Management System documentation of the Organization is complete.
- The Quality Management System documentation of the Organization is partially complete.
- The Quality Management System documentation of the Organization does not exist.

Besides determining the status of the organization's document adequacy, the QMS Document Management System will be able to provide recommendations and suggestions to improve the quality of documentation. The documents must be on par with the ISO 9001 standards.

On the other hand, in Internal Quality Audit, the expected goals are:

- Qualified for ISO 9001:2000 Standard and
- Not Qualified for ISO 9001:2000 Standard.

System input: The input from the users will be in the form of answering the Expert System's multiple choice questions and short answered questions. The questions will relate to the criteria of the Adequacy Audit and Internal Audit for the ISO 9001 process. The goal of the questions is to determine the adequacy of the documents and the qualification status of the Quality Management System of an organization.

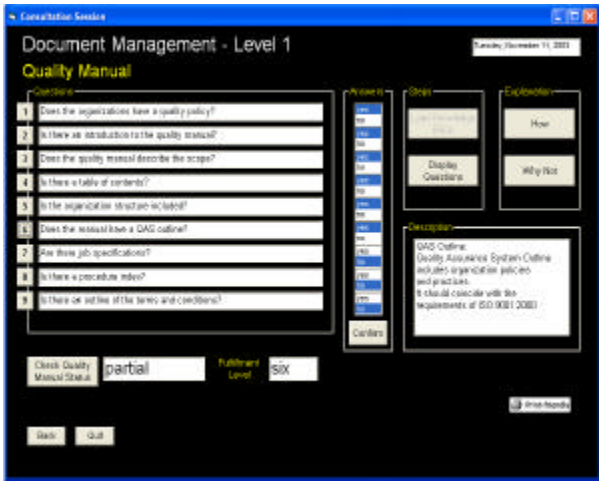

Fig. 10: A view of the adequacy audit

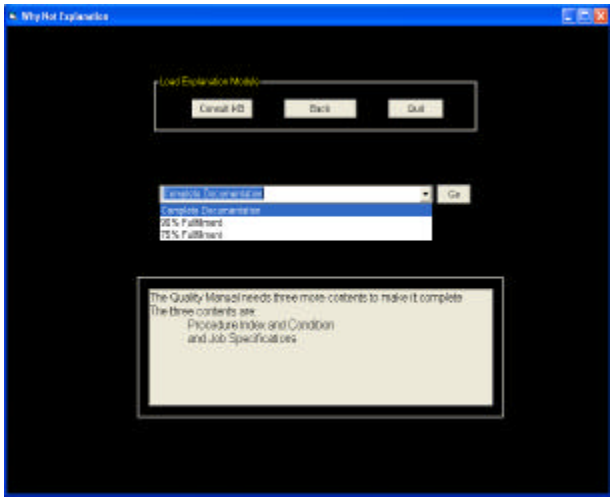

Fig. 11: Why-not explanation page

Methods of knowledge acquisition: The basic model of knowledge engineering portrays teamwork in which the knowledge engineer, for which in this project are the authors, mediates between the expert and the knowledge base. The knowledge engineer elicits knowledge from the expert, refines it with the expert and represents it in the knowledge base. The elicitation of knowledge from the expert can be done manually or with the aid of computers. There are basically three methods of knowledge acquisition. The type of method chosen and applied in this project is the manual methods. The methods involved in manual knowledge acquisition (Fig. 5). The techniques used within manual methods were unstructured interviews and observations.

Domain expert is first sourced who is the manager for Consultancy and Quality Assurance Centre of UNITEN. The Documented Knowledge was in the form of modules mentioned in the beginning of this chapter. The modules were such as Introduction to ISO 9001:2000 Quality Management System-UNITEN Internal Training[3] and Internal Quality Audit Training Audit by Pusat Perundingan and Jaminan Kualiti UNITEN[4].

Besides interviewing, the authors managed to gather knowledge through observations, in which they observed the domain expert audited some firms. This is the most obvious and straightforward approach to knowledge acquisition. The first instance was during the QMS Mock Audit of TNB-Fuel. The second observation was made during a ISO 9001:2000 Documentation Training.

Framework for the proposed solution

Knowledge representation method: A variety of knowledge representation schemes have been developed over the years. The two common characteristics of all these schemes are that they can be programmed with existing programming language and stored in memory and also that they are designed so that the facts and other knowledge within them can be used for reasoning. Knowledge captured from experts and other sources must be organized in such a fashion that a computer inferencing program will be able to access this knowledge whenever needed and draw conclusions. In our Expert System, production rules is used.

Implementation tools selection: The expert system is built from scratch using a declarative programming language instead of conventional procedural programming. The latter requires that the programmer tell what to do That is, how to get the output for the range of required inputs. The programmer must know an appropriate algorithm. In contrast, declarative programming requires a more descriptive style. The programmer must know what relationships hold between various entities.

The selected tool: The favored programming tool is AMZI! Prolog. It supports the main inference method described in the next section.

Inference methods: There are two approaches for controlling inference in rule-based ES which are forward chaining and backward chaining. The QMS Document Management ES will apply both methods. However, the system will use mostly backward chaining. A brief description of both inference methods are stated below.

- Backward chaining: is a goal-driven approach in which you start from an expectation of what is to happen (hypothesis), then seek evidence that

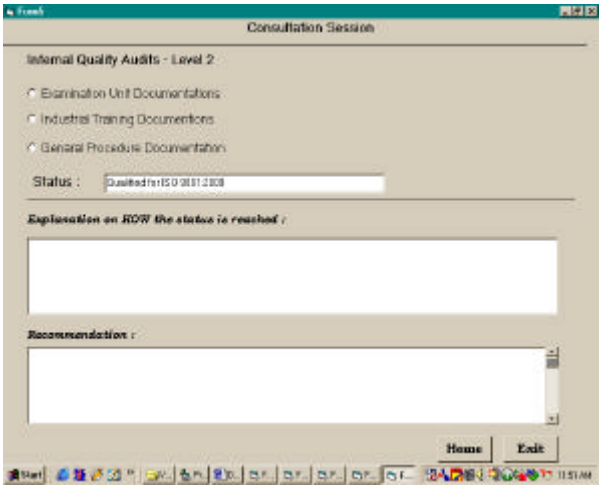

Fig. 12: HOW explanation page

supports (or contradicts) your expectation. Often this demands formulating and testing intermediate hypotheses or sub goals. The computer analyses the problem by looking for the conclusion that match the THEN portion of its IF-THEN rules.

- Forward Chaining: is a data-driven approach. In this approach you start from available information as it comes in, or from a basic idea, then try to draw conclusions. The computer analyses the problem by looking for the facts that match the IF portion of its IF-THEN rules.

This inference method is chosen as the inference method because there will only be three conclusions regarding the documentation status of an organization, namely: No documentation, Complete documentation and Partial documentation. While in the auditing process the outcome will be either Qualified or Not qualified for ISO 9001:2000 certification.

System architecture for the expert system: Figure 6 shows the components in our expert system.

Abstraction of model semantics: Since the system is a rule-based system, the knowledge must be organized in term of rules. The knowledge acquired from the expert, is represented by production rules and inference trees.

Sample rules for documents management use: The rules are categorized as general goals and sub goals.

General rules (general goals)
IF level 1 AND level 2 AND level 3 AND records are completed
THEN complete documentation
IF level 1 OR level 2 OR level 3 OR records exist
THEN partial documentation
IF level 1 AND level 2 AND level 3 AND records does not exist
THEN no documentation

Quality manual-level 1 document (sub goal)
IF there's vision AND mission
THEN quality policy exists
IF there's no vision OR mission
THEN quality policy does not exist
IF quality policy exists
THEN check organization structure
IF organization structure exists
THEN check job specification
IF job specification exists
THEN check QAS outline
IF QAS outline exists
THEN check procedure index
IF procedure index exists
THEN check conditions
IF conditions exists
THEN check TOC
IF TOC exists
THEN check scope
IF scope exists
THEN check introduction
IF there's introduction AND scope AND TOC AND conditions AND procedure index AND QAS outline AND job specification AND organization structure AND quality policy
THEN quality manual is complete
IF there's introduction OR scope OR TOC OR conditions OR procedure index OR QAS outline OR job specification OR organization structure OR quality policy
THEN quality manual is partially complete
IF there's no introduction AND no scope AND no TOC AND no conditions AND no procedure index AND no QAS outline AND no job specification AND no organization structure
THEN there is no content
If there's no content OR no quality policy
THEN quality manual does not exist
IF no content exists
THEN quality manual does not exist
IF quality policy does not exists
THEN quality manual does not exist
IF organization structure does not exists
THEN quality manual partially complete
IF job specification does not exists
THEN quality manual partially complete

IF QAS outline does not exists
THEN quality manual partially complete
IF procedure index does not exists
THEN quality manual partially complete
IF Quality Manual conditions does not exists
THEN quality manual partially complete
IF TOC does not exists
THEN quality manual partially complete
IF scope does not exists
THEN quality manual partially complete
IF intro does not exist
THEN quality manual partially complete

An example of inference tree for "not qualified" status in exam paper marking scheme of the exam unit, UNITEN: The inference tree or in another name, goal tree provides a schematic representation of the inference process. When drawing the inference tree, the premises and the conclusions are shown as nodes. The branches are used in order to connect the premises and the conclusions. The inference tree is made up from the root at the top and branches point downward and ultimately ends with facts or dead ends that do not have sub goals anymore. As mentioned earlier, there are two inference trees that have two different goals in auditing each documentation, which are QUALIFIED for ISO 9001:2000 Standard and NOT QUALIFIED for ISO 9001:2000 Standard. Fig. 7 shows the inference tree design for "Not Qualified" status.

Design of main interface and consultation pages
Main interface: To use the system, user would require to run the qms.exe file. Once invoked seen in Fig. 8 will appear.

Consultantion views: The consultation page is one that starts the auditing process. The page will display a series of question and await for user response. Depending on the answers provided by the user, the system will draw a conclusion for a conducted session.

Explanation pages: Some screen shots in respond to clicking on the How and Why-Not explanation buttons are shown in Fig. 11 and 12.

Knowledge-base maintenance: Facts can be updated (add, delete and change) via the following interface (Fig. 13). Access to this page is granted for authorised users only.

Prototyping essentials: Software that are essential in the prototype development are as follows:

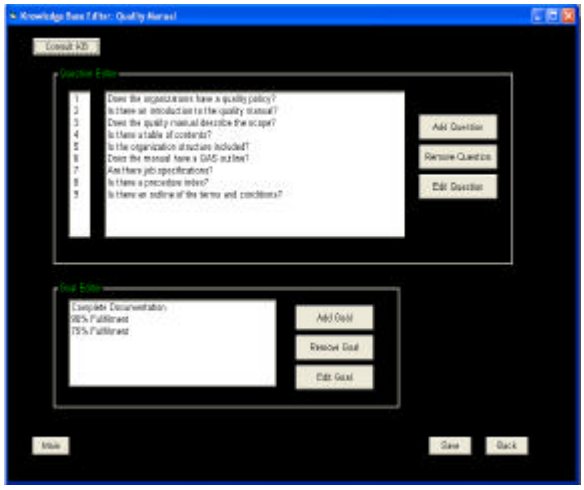

Fig. 13: Editor for facts maintenance

- AMZI! Prolog 6.2.2 IDE
  - Compiler-Compiles Prolog source to machine-independent byte codes.
  - Linker-Links multiple Prolog byte-code files into a single unit.
  - Listener/Debugger-Interactive environment for testing Prolog code.

- AMZI! Logic Server
  - Logic Server-The virtual machine that runs Prolog code.
  - Logic Server Application Program Interface (API)-The interface that allows application programs written in other environments to easily integrate with Prolog.
  - Microsoft Visual Basic 6.0

What is AMZI! Prolog + logic server?: AMZI!® Prolog + Logic Server™[5] makes it easy to integrate rule-based components with Windows, Linux, Sun Solaris and other applications. AMZI! also offers plug-in, rule-based services for C, C++, Java, Web Servers, Delphi, VB.NET, C#.NET and a few more. The integration is achieved through the Logic Server API (Fig. 14). The programming interface to the Amzi! run-time is called the Logic Server API. It mimics the functionality of the Prolog listener. Source and object code can be loaded, queries are issued, assertion of new facts are also made possible.

Implementation: This system is divided into two main parts, which are the Visual Basic and Prolog components. The Visual Basic part of the system is then broken down into two types of program files. They are Visual Basic

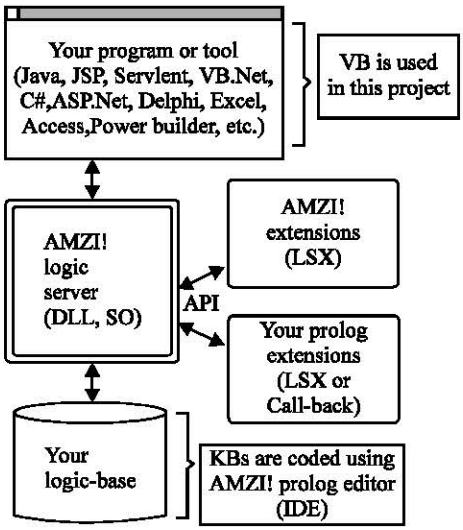

Fig. 14: Logic server and related components[5]

forms (.frm) and Visual Basic modules (.bas). Similarly, the Prolog part of the system consists of two types of files which are the Prolog Source files (.pro) and the compiled Prolog shell (.xpl). Figure 8 shows the main page of the expert system. The consultation window is the heart of the system invoking rests of the function such as QandA, inferencing and explanation about 'How', 'Why Not' and 'Why' a conclusion is reached (Fig. 9-12). To enable the functions in VB form to call knowledge bases coded in Prolog, AMZI! Logic Server 6.2.2 is used. For this, the files amzi.dll and amzi.bas must be included in the system folders. There is also a Knowledge base (KB) editor to allow authorised user to update the KB without having to code it using Prolog text-based editor but through the Graphical User Interface. To achieve this, simple shells (or engines) are developed.

A prototype for the QMS expert system has been developed. It is a working version that can assist the department in the initial stage of the certification process. This prototype contributes to the research, development and also the growing needs of expert systems in QMS auditing. The system is easy to use and is able to provide recommendation and explanation on documents fulfillment level and certification status. Besides that, the system provides simple facts maintenance. Users are able to change specific facts through the interface. The edited facts are automatically formatted into prolog clauses.

An interesting progress that can be made is by exploring the potential of applying fuzzy rules into the system. This will improve the rigidness of yes and no answers. The group will also explore on the possibility of using Natural Language Processing (NLP) in the answering part of the auditing process.

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