Developing Web-Based Semantic Expert Systems

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Abstract

Expert systems have provided solutions to different problems, from strategic planning of marketing to consulting in process reengineering. In general, the majority of studies published are based on advanced techniques of artificial intelligence, using specific languages or tools that require certain knowledge of reasoning processes to model information.

With the advent of the Internet and its evolution, web-based expert systems have become very important. Moreover, the arrival of web-based expert systems that can connect to the Internet has made it easy to access information from any place at any time, creating new requirements for web systems.

In this research, a tool is proposed for development of web-based expert systems and utilizes Semantic Web technology which permits the knowledge engineer and domain expert to define the knowledge without having to know anything about programming languages and AI.

The proposed tool enables the knowledge engineer to insert and update the domain knowledge; facts and rules. The facts of the knowledge can be annotated using the semantic concepts and relations found in WordNet ontology. The tool can induce new rules based on the annotated semantic concepts and relations. Using Semantic Web technology supports the tool to utilize the ontology as knowledge formalization. Using the proposed tool, the Web-based expert system can be developed simply and takes short time by using its knowledge base, inference engine and Web-based user interface.

Keywords: Expert System, Expert system tool, WordNet, Knowledge base.

1. Introduction

Expert systems (ES) may contain knowledge from several human experts, giving them more breadth and robustness than a single expert [2]. Web based ESs have several factors that make the platforms, by contrast to standalone platforms, an ideal base for KBS (knowledge based system) delivery. These factors include [1]

- The Internet is readily accessible,
- Web-browsers provide a common multimedia interface,
- Several Internet compatible tools for KBS development are available,
- Internet-based applications are inherently portable, and
- Emerging protocols support co-operation among KBS.

The architecture of WBES [6] is based on the traditional expert of system technology with an integration of web technology at various modules of the system. The organic design of traditional expert system architecture has been adapted to Internet use by incorporating client-server architecture and web browser-based interfaces [7].

A general architecture of WBES is shown in Figure 1.

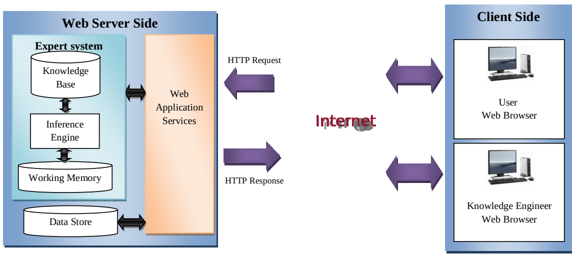

Figure 1: The general architecture of WBES

There are powerful tools for the generation of expert systems [8]. However, creating an expert system on the basis of these tools becomes a very difficult task for users without specific training in small and medium-sized companies. A tool that is easy to use but still has enough power to solve problems and can be used by the domain expert makes the technology of expert systems accessible in all types of companies [8].

An expert system shell is an expert system with an empty knowledge base. A shell contains the framework with all the specific strategies for inference and knowledge representation incorporated [9] as found in expert system development life cycle [3]. The expert system development life cycle consists of nine phases, as shown in Figure 2.

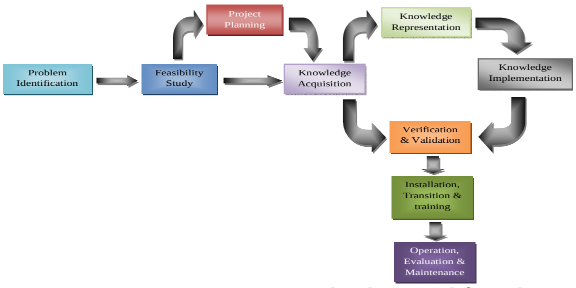

Figure. 2: Expert system development life cycle

Knowledge representation [3, 12] involves representing the key concepts and relations between the decision variables in some formal manner, typically within a framework suggested by an expert systems shell. Most representation mechanisms must provide support for three aspects of knowledge conceptual representation, relational representation, and uncertainty representation. As such, four schemes are commonly used for knowledge representation.

An inference engine [13] stands between the user and knowledge base. The inference engine, including Inference and Control, performs two major tasks. First, it examines existing facts and rules, and adds new facts when possible. Second, it decides the order in which inferences are made. In doing so, the inference engine conducts the consultation with the user.

The inference engine [14] uses the information in the working memory along with the rules in the knowledge base to derive the conclusions. There are two basic ways a rule-based system operates: backward and forward chaining.

The Semantic Web [15] "transforms the Web by providing machine understandable and meaningful descriptions of Web resources". Making the Web content machine understandable, allowing agents and applications to access a variety of heterogeneous resources, processing and integrating the content, and producing added value for the user. The semantic web [17] adds structured meaning and organization to the navigational data of the current web, based on formalized ontologies and controlled vocabularies with semantic links to each other. WordNet [19] is a lexical database representing semantics relations among words. It provides rich semantic relations of words including synonym, antonym, and so on with which words are linked together to form a network.

2. Related Work

Kumar and Mishra have discussed and explained the various domains for WBESs in [6]. They summarized and provided observations on few of the representative WBESs in Engineering, Management, Medicine, Education, Agriculture, Finance, and Tourism domains. Observations and comparisons on the different factors like knowledge representation, inference, user interface, use of various web services-related processes, and applications have been tabulated for WBESs of each domain.

Chorbev, Mihajlov and Jolevski have presented in [20] a web based medical expert system that performs self training using a heuristic rule induction algorithm. The system has a self training component since data inserted by medical personnel while using the expert system is subsequently used for additional learning. The test use of the system in a public hospital generated positive feedback from the physicians using it. The self training function is expected to fine tune the classification and to adapt it to health issues that are endemic in the region of use.

Shue, Chen and Shiue presented in [21] the approach in developing an expert system for assessing financial quality of an enterprise by separating the knowledge body into domain knowledge and operational knowledge. They represented the well defined relationships between various accounting categories and items, and the latter refers to the analytical processes of utilizing the domain knowledge for assessment. They applied the ontology to model the domain knowledge and used production rules to represent the operational knowledge.

In [22], the earthquake disaster management planning in the practical problems used OWL DL to describe the state and characteristics information of the earthquake. On this basis, by introduction of logical reasoning, the authors gave an earthquake rescue planning process on case-based case database and knowledge database. They made full use of existing domain knowledge to support decision-making personnel rescue program for improving the efficiency of case retrieval, and optimize the rescue program has played a positive role.

Prcela, Gamberger, and Jovic described the utilization of OWL in medical expert systems applications in [23]. They presented the descriptive ontology constructed for the heart failure domain and then analyze the possibility to include also procedural knowledge in the same ontological representation. Finally, based on experiments with real application they compared rule based reasoning with onological reasoning for the procedural type of the knowledge.

Sahin, Tolun and Hassanpour in [24] have surveyed several recent publications around the intersection of neural networks, expert systems domains and specifically concentrated on recent trends in hybrid expert system development. The review papers were evaluated with respect to Hybrid Expert System structure approaches, algorithms, application categories and building/implementation tools.

Dunstan in [25] has described the method that generates web-based expert systems from XML descriptions of the knowledge domain. The method relies on an XML parser which converts domain knowledge into Prolog code. Web pages dynamically interpret the code to provide expert system responses to the user. A case study was developed which showed that university course rules could be expressed in XML format, and directly converted into Prolog code. The XML parser can also generate course-specific HTML and CGI files as components in a course-specific web-based enrollment guide.

A novel approach to forecast plant equipment faults that is not dependent on complex equipment or mathematical models is discussed in [26]. It uses the sensor data collected by Supervisory Control and Data Acquisition Systems (SCADA). The large amount of data collected by SCADA is used only for monitoring purpose by SCADA system, which is effectively used here. This approach provides early warning of abnormal conditions and also provides information about how to prevent fault causes. Early forecasting reduces equipment down time and maintenance costs. It also provides a safer environment to work with.

The concept of ontology in knowledge engineering is introduced in [27] to construct the engine fault diagnosis system (EFDS). Considering the reasoning in the ES of Engine fault diagnosis and the knowledge structure based on Ontology, the domain-ontology knowledge base, structure definition of the fault diagnosis system and reasoning description are discussed. Ontology knowledge base of automobile engine fault diagnosis is constructed primarily. Owing to OWL-API and Inference API in Jena and protégé are employed to implement the description and reasoning driver of the KB, it facilitates implementation of the cross platform, portability, reusability, Internet-based, and remote diagnosis of this system.

Chitra, Ahmad and Mahsa addressed the TKT-OAV tool for construction of new unique knowledge base in knowledge based systems in [28]. The major objective of this work was to design an user friendly tool to construct a knowledge base which knowledge present in semantic network or frame knowledge representation techniques easily and transform the knowledge of any expert system to the unique knowledge representation technique, Ex-OAV KB. This tool could help the knowledge engineer to validate and verify all knowledge base, based on different knowledge representation techniques in expert systems.

Thomas and Russomanno proposed in [29] an ontology-based approach to heterogeneous sensor fusion with the use of SWEXSYS, which is a Prolog based expert system shell developed for reasoning with data, metadata, and knowledge expressed on the Semantic Web. As an initial application, they have implemented in SWEXSYS an approach to level one fusion using the theory of uncertainty to make classifications of objects captured by sensors.

The design and development of a web based expert system shell and its role in developing an Intelligent Fault Diagnosis and Control Paradigm (IFDCP) package for power system equipment is presented in [30]. A brief description of expert system architecture and issues involved in developing a web based expert system shell and the technology used is discussed. The concept of designing a web based expert system with a user friendly GUI is also discussed. The application of the shell to develop the package IFDCP for fault diagnosis and control of general power system equipment which provides online help for diagnosing faults of electrical power equipment and clearing them is discussed in detail in the paper. The package deals with data collected from an electrical factory in Visakhapatnam for Transformers, DC Motors, AC Motors and Street Lamps.

3. The Proposed Architecture

There are powerful tools for the generation of expert systems. However, creating an expert system on the basis of these tools becomes a very difficult task for users without specific training in small and medium-sized companies. A tool that is easy to use but still has enough power to solve problems and can be used by the domain expert makes the technology of expert systems accessible in all types of companies.

In the present information society, companies must be able to create new solutions in increasingly shorter periods of time. As such, the creation of new web-based expert systems must support access and provide tools that facilitate the rapid development of these systems.

This work aims at proposing a Web-based tool which allows the construction and development of an expert system based on Web. This tool allows the creation of an expert system using rule-based representation of knowledge. The knowledge, that is facts and rules, is represented firstly in XML format [1]. The tool uses the ontology; that is WordNet [18, 19], to add semantics to the facts, and then the knowledge is represented in ontological format.

The proposed tool enables knowledge engineer to perform these tasks:

1. Building knowledge base of the expert system.
   a. Insert the knowledge facts and insert the knowledge rules.
   b. Update the facts and the rules.
2. Annotating the facts to incorporate the semantic content of the facts to build the semantically enhanced facts using domain related concepts based on concept hierarchies in WordNet [18, 19]. This task is performed by using semantic similarity based on WordNet ontology.
3. Representing the knowledge in the ontological.
4. Automatic inducing new rules based on the semantic of the facts using the found rules.

The proposed tool enables domain expert to perform these tasks:

- Verification and Validation created knowledge.
- Verification and Validation the induced rules.

The general architecture of the design for the proposed tool is shown in figure 3.

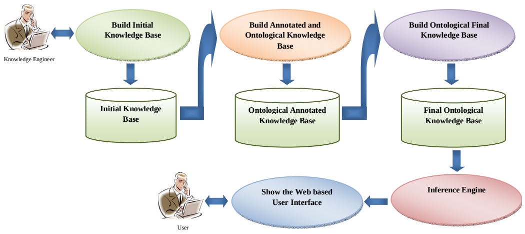

Figure 3: General architecture of the proposed tool

The proposed tool has three stages during building the knowledge base:

- Building the initial knowledge base,
- Building the annotated and ontological knowledge base,
- Building the ontological final knowledge base, and
- Building the Web-Based Expert System.

3.1 Building the initial knowledge base

The first stage contains the tasks to enter the facts and the rules of the domain knowledge. This stage is shown in figure 4.

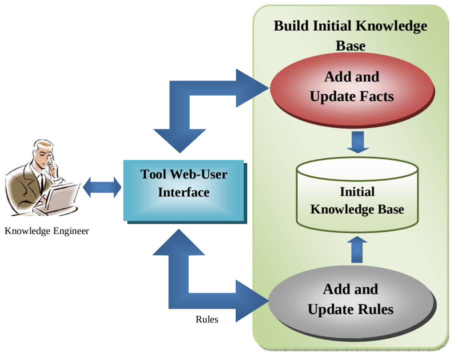

Figure 4: The first stage of the tool

A precise domain is required by an expert system, the domain must be compact and well organized. The quality of knowledge highly influences the quality of expert system. The knowledge base is the core component of any expert system; it contains knowledge acquired from the domain expert. Building the knowledge base with the help of domain expert is the responsibility of knowledge engineer. The first task of any expert system development is the knowledge acquisition [33]; which is one of the most important phases in the expert system development life cycle. The process of knowledge acquisition is difficult especially in case if the knowledge engineer is unfamiliar with the domain. The goal of knowledge acquisition step is to obtain facts and rules from the domain expert so that the system can draw expert level conclusions. Figure 5 shows the algorithm of saving new model, rule attribute, and finding. Figure 6 shows saving new rule attribute and finding for the same model.

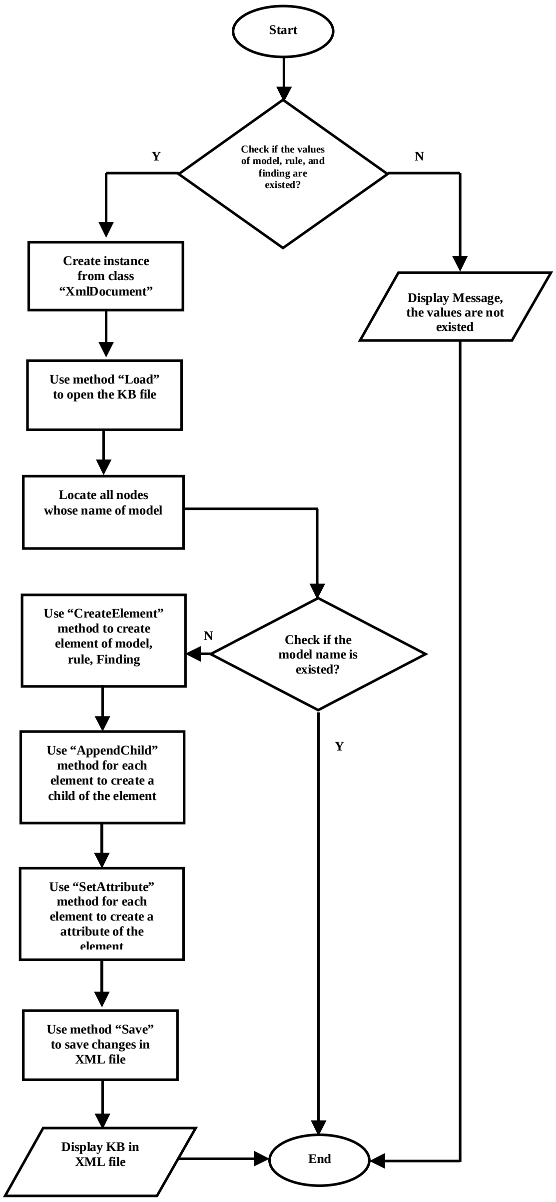

Figure 5: The algorithm of saving new model, rule attribute, and finding

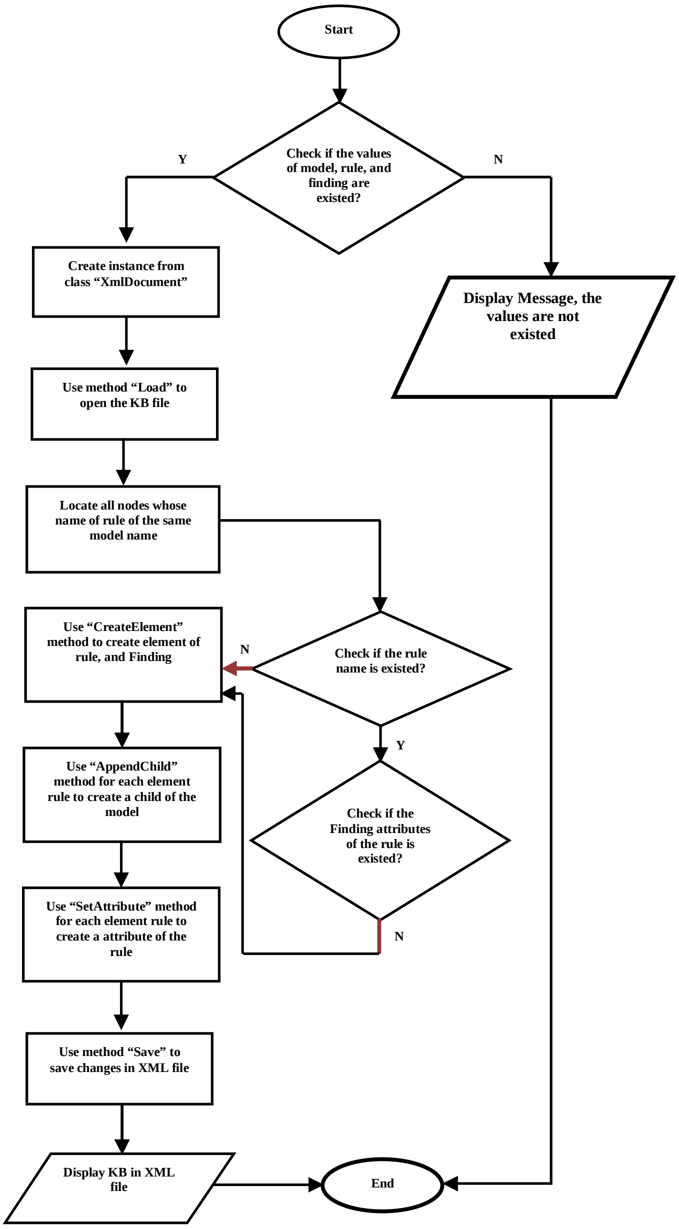

Figure 6: The algorithm of Saving new Rule Attribute and Finding for the same Model

3.2 Building the annotated and ontological knowledge base

The second stage has the tasks to annotate and represent the knowledge. This stage is shown in figure 7.

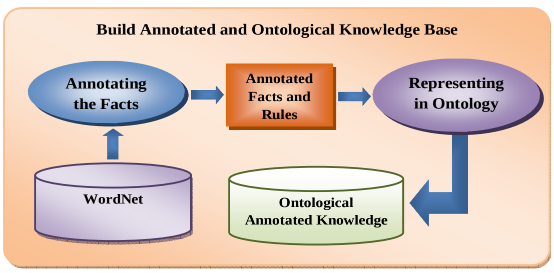

Figure 7: The second stage of the tool

In this stage of the proposed tool, the method based on WordNet [19] is used to acquire the related concepts of the certain concept in the knowledge. WordNet is ontology of cross-lexical references whose design was inspired by the current theories of human linguistic memory. English names, verbs, adjectives and adverbs are organized in sets of synonyms (synsets), representing the underlying lexical concepts. Sets of synonyms are connected by relations. The basic semantic relation between the words in WordNet is synonymy [19]. Synsets are linked by relations such as specific/generic or hypernym /hyponym (is-a), and meronym/holonym (part-whole). The principal semantic relations supported by WordNet is synonymy: the synset (synonym set), represents a set of words which are interchangeable in a specific context.

The knowledge engineer, working with the expert, must try to define the possible best structure. Other commonly used approaches include decision trees, blackboard systems and object oriented programming. Knowledge representation has been defined as "A set of syntactic and semantic conventions that make it possible to describe things. The syntax of a representation specifies a set of rules for combining symbols to form expressions in the representation language. The semantics of a representation specify how expressions so constructed should be interpreted (i.e. how meaning can be derived from a form). In the proposed tool, the knowledge representation methodology uses XML format [1]. Where, two elements of knowledge, ontology and model rules are represented using XML format. The overall knowledge structure is shown in figure 8.

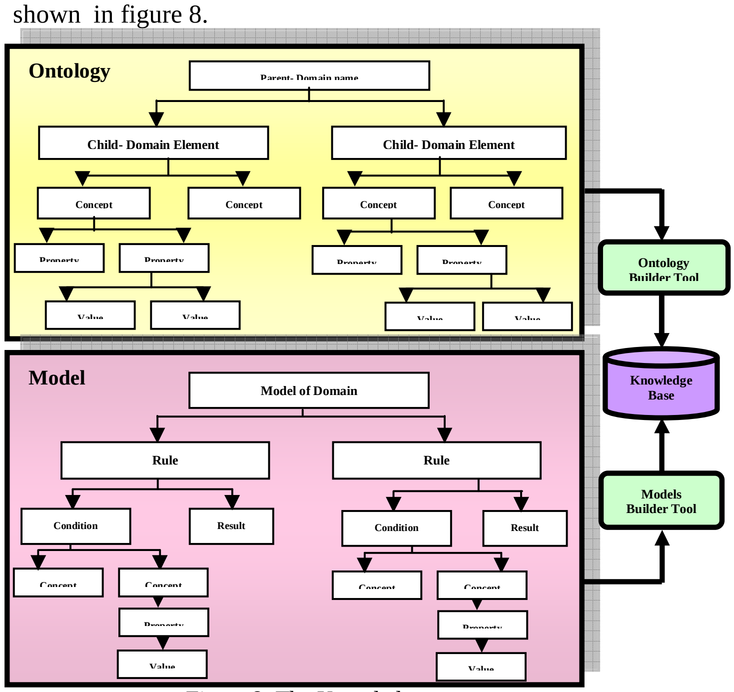

Figure 8: The Knowledge structure

3.3 Building the ontological final knowledge base

The third stage has the tasks to induce, verification and validation for the knowledge. This stage is shown in figure 9.

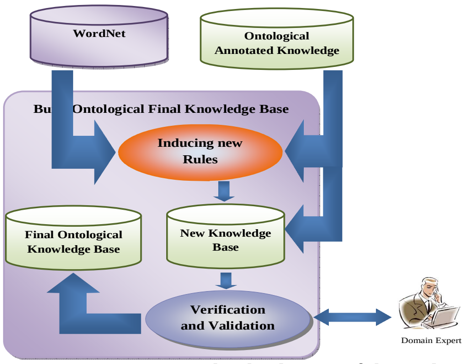

Figure 9: The third stage of the tool

WordNet categories [31] are used to induce new rule by maping all the concepts in the knowledge into their lexical categories. For example, the word "dog" and "cat" both belong to the same category "noun.animal".

After the step of the domain identification and knowledge acquiring from a participating expert of specific domain, a model for representing the knowledge must be developed [32]. Numerous techniques for handling information in the knowledge-base are available; however, most expert systems utilize rule-based approaches. Domain expert should verify new rules in the knowledge and he can validate the rule if the induced rule need to be adjusted.

3.4 Building the Web-Based Expert System

The fourth stage has the tasks to build the inference engine and Web-based user interface. This stage is shown in figure 10.

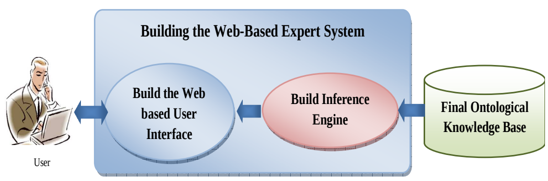

Figure 10: The fourth stage of the tool

The entire architecture of the proposed tool is shown in figure 11.

The inference mechanism consists of three main components namely: working memory manager (WM manager), XML matcher, and result browser.

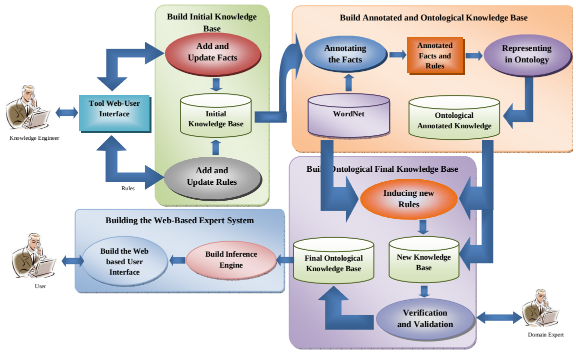

Figure11: The entire architecture of the proposed tool

- WM Manager Component: The WM manager interacts with the user-friendly interface to get the concepts and its properties as well as the values of those properties b y using communication model. The user-friendly interface permits the user to edit his complaints easily. This complaint is considered as a user finding. When the user selects concept, property, and value to be entered in the working memory, the WM manager creates an XSL query statement, which represents these findings.
- XML Matcher Component: In this methodology the rule is succeeded when all its child nodes are existed in working memory. This is achieved when the attribute 'ExistInWM'of every child node is set to "Yes". So, the matcher gets those succeeded rules by comparing the value of the attribute 'NoTrueFindings' of every parent node and the number of the child nodes in this rule and select the matched one. The succeeded rules are store in the result store for later use by display result component.
- Result Browser Component: Result Browser component gets the value of the attribute disorder for every rule in the result store, and pass value to the user interface b y using communication model to display it to the user.

Figure 12 shows the flow chart for the inference engine implemented in the tool.

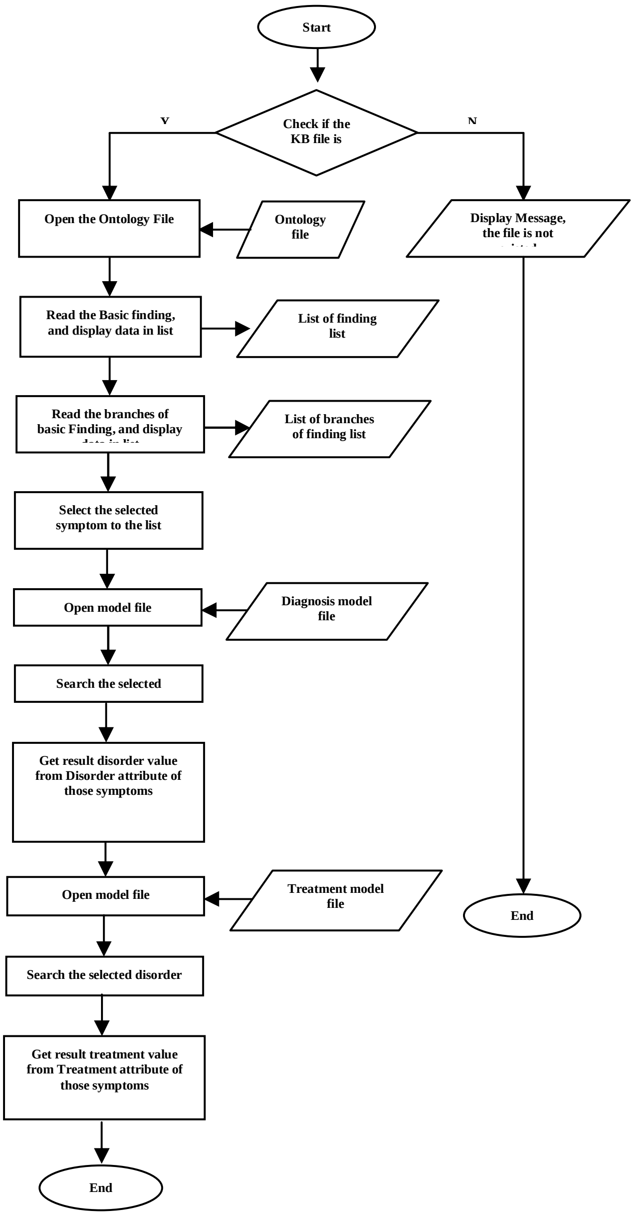

Fig. 12: The flow chart of the inference engine of the tool

4. Conclusions

1. CONCLUSION

The proposed tool is a web based tool to develop expert systems (ES). The web based tool made the evaluation and maintenance of the ES easier than a conventional expert system tool.

Compared with traditional ES development tools, the web design software simplifies the user interface design. XML-based user interfaces allow the incorporation of rich media elements. Hyperlinks provide an extra facility in enhancing ES explanation and help functions; users can access the relevant web site easily. Also, the WWW helps in acquiring the knowledge needed in constructing the knowledge base.

Any knowledge updating and maintenance can be handled centrally. Useful links are incorporated to help the user understand and interpret the ES recommendations. The proposed tool facilitates the simple and fast creation and exploitation of web-based expert systems which are accessible via web browsers as well as mobile devices. This tool can provide the semantic data to the facts in the knowledge and represent the knowledge in the ontological format.

The proposed tool has capability to annotate the knowledge in the initial knowledge base, and then represent the knowledge in the ontology language. The ontological representation of the domain knowledge enables other systems to reuse this knowledge and to share this knowledge. This representation also makes this knowledge is understandable to the machine and can be processed by the programs and agents.

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