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APPLICATION OF EXPERT SYSTEM FOR DIAGNOSING MEDICAL CONDITIONS: A METHODOLOGICAL REVIEW

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ABSTRACT: *Naturally, human diseases should be treated on time; otherwise the patients might die if there is delay in attending to such patient or scarcity of medical practitioners' or experts. Several attempts have been made through studies to design and built software based medical expert systems for probing and prognosis of several medical conditions using artificial and non-artificial based approaches for patients and medical facilities. This paper represents a comprehensive methodological review of existing medical expert systems used for diagnosis of various diseases based on the increasing demand of expert systems to support the human experts. The study provides a concise evaluation of the various techniques used such as rule-based, fuzzy, artificial neural networks and intelligent hybrid models. The rule-based techniques is not too efficient based on its inability to learn and require powerful search strategies for its knowledge-base; while the fuzzy or ANN models are less efficient when compared to the hybrid models that can give a more accurate results.*

KEYWORDS: Expert system, AI, Fuzzy Logic, ANN, Rule-based, intelligent hybrid model

INTRODUCTION

Expert system (ES) is a complex software designed with the abilities to reason and think like human expert in a particular key domain area using rules (Gath and Kulkarni, 2012; Nohria, 2015; Abu-Nasser, 2000; Santosh, Dipti and Indrajit, 2010; Soltan, Rashad and El-Desouky, 2013; Hambali, Akinyemi and Luka, 2017; Keles, 2014).

ES belongs to a branch of Artificial Intelligence that engages the usage of human knowledge to solve complex issues that requires the human expert to naturally probe and diagnose using clinical aids (Mishra, Painuli, and Nirvikar, 2016; Gath and Kulkarni, 2012; Nohria, 2015; Abu-Nasser, 2000; Soltan, Rashad and El-Desouky, 2013; Fatumo, Adetiba and Onaolapo, 2013).

An ES can be designed using the traditional or classical rule-based technique that does not have much learning abilities or with techniques such as fuzzy logic commonly referred to as fuzzy based expert system or artificial neural network expert system, or hybrid approach (neuro-fuzzy expert system) which has learning abilities and intelligence.

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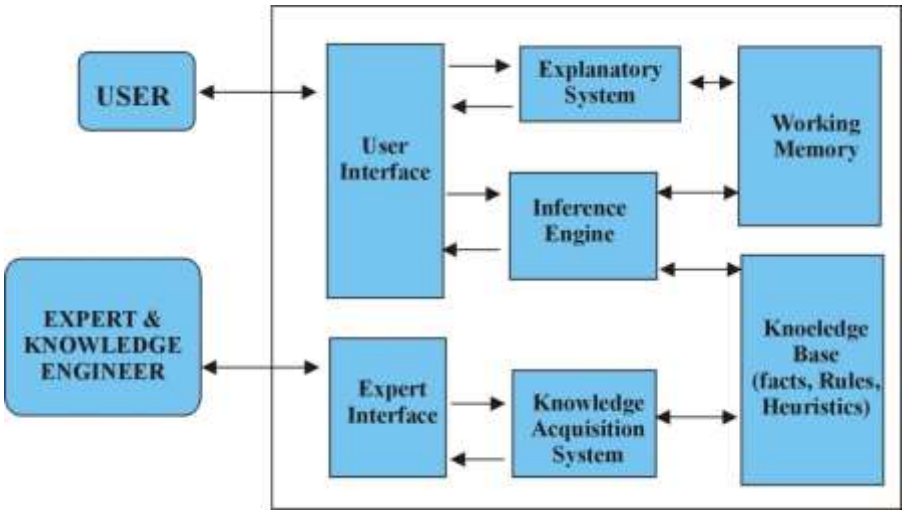

Figure 1: Typical architecture of an expert system (Abu-Nasser, 2000)

According to Abu-Nasser (2000) Expert system has five main components; and they are as follows:

i. **Knowledge Base:** The knowledge base helps to handle set of rules in a specific knowledge domain area.
ii. **Inference Engine:** The inference engine helps to handle input request from the user interface, and matches it with the rules / facts in the knowledge base in order to conclude based on given inference.
iii. **Explanation Facility:** The explanation facility simply explains to the user the reasoning process of the expert system.
iv. **Knowledge Engineer:** A knowledge engineer is a highly skilled person who can handle the design, development, testing and maintenance of an expert system. The knowledge engineer seeks for the real knowledge and experience of a human expert in key domain area; and then transfers such knowledge to the computer expert system.
v. **Interface:** The interface gives the user access authority to the expert system.

The traditional or classical approach of designing expert system relied so much on rule-based techniques. A rule-based system consists of IF-THEN rules, which is a cluster of facts, and a translator monitoring the presentation of the rules, given the facts. These IF-THEN rule statements are used to express the conditional statements that embrace the complete knowledge base. A single IF-THEN rule adopts the form IF c is A then z is B; the IF part of the rule "c is A" is referred to as the antecedent or premise, while the THEN part of the rule "z is B " is referred to as the consequent or conclusion.

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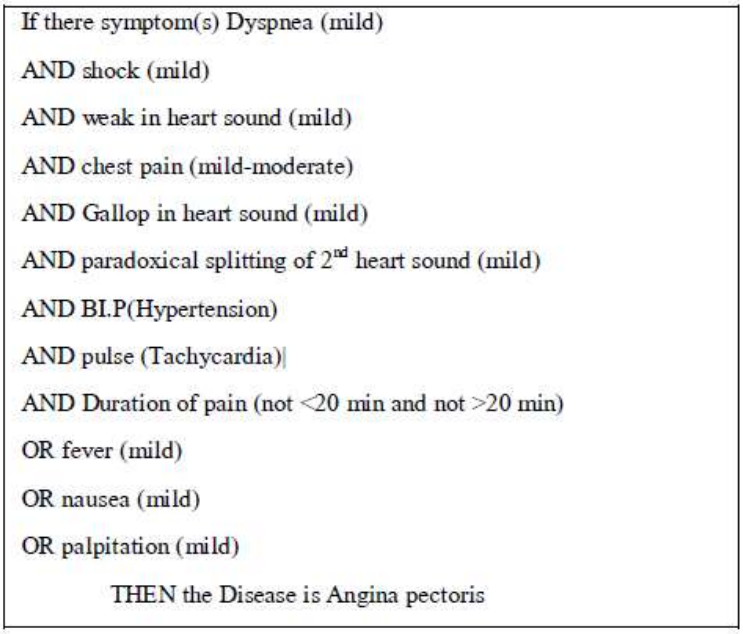

Figure 2: An Example of Production Rule (Soltan, Rashad and El-Desouky, 2013)

Two types of inference engines commonly being used in rule-based systems: forward chaining and backward chaining systems. The forward chaining is data-driven reasoning process; the reasoning starts from the known data and proceeds forward with that data to a conclusion. The backward chaining is a goal-driven reasoning process, in which the expert system has the goal i.e. a hypothetical solution, and the inference engine tries to find the sign to substantiate it.

According to Santosh, Dipti and Indrajit (2010); the traditional rule-based expert system have been used over the years for diagnosing medical conditions such as Angina pectoris (Soltan, Rashad and El-Desouky, 2013), Myocardial Infarction (Fatumo, Adetiba and Onaolapo, 2013), Malaria and Typhoid Fever (Tunmibi, Adeniji, Aregbesola and Ayodeji, 2013), Lassa Fever (Hambali, Akinyemi and Luka, 2017), Influenza (Hossain, Khalid, Akter, and Dey, 2014), Cardiological diseases (Bursuk, Ozkan, and Llerigelen, 1999), Eye diseases (Ibrahim, Ali, Jaais, and Taib, 2001), Viral infection (Patel, Patel, and Virparia, 2013), Lungs disease (Singla, 2013), and Memory loss (Komal and Vijay, 2014).

However, these rule-based expert systems are prone to issues of inability to learn, ineffective search strategy, opaque relations between rules, and so on.

Fuzzy Expert System

A Fuzzy Expert System is a gathering of membership functions and fuzzy rules. These functions and rules are used to reason concerning the data. It accepts numbers as input, and thereafter transforms the input numbers into linguistic variables like Short, Moderate and Tall. This variation is titled fuzzification (Nohria, 2015).

It is the duty of the Rules to map the input linguistic terms against related linguistic terms that concerns the output. This job is done by fuzzy Inference engine. Lastly, the translation of the output linguistic expressions intense on an output number is done. This adaptation is referred to as defuzzification. It is noted that all the fuzzy rules and linguistic variables are stored in fuzzy knowledge base.

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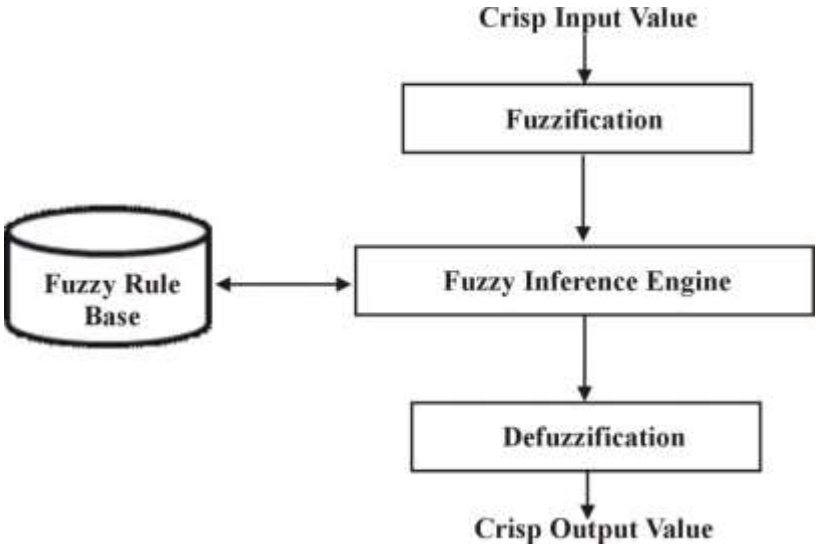

Figure 3: Fuzzy Expert System (Kaur and Bhardwaj, 2014)

The research scholars such as (Imianvan and Obi, 2012; Ajenaghughrure, Sujatha and Akazue, 2017; Osaseri, Onibere and Usiobiafo, 2014; Abdullah, Zakaria, and Mohammad, 2011; Neshat, Yaghobi, Naghibi, and Esmaelzadeh, 2008; Imianvan and Obi, 2011a; Ekong, Onibere, and Imianvan, 2011; Imianvan, Obi, and Ehigiator, 2011; Obi and Imianvan, 2011c; Imianvan and Obi, 2011c; Imianvan, Anosike and Obi, 2011; Imianvan and Obi, 2012b; Obi and Imianvan, 2012b; Imianvan and Obi, 2012c; Obi and Imianvan, 2013a; Obi and Imianvan, 2013b; Imianvan, Ogini, and Obi, 2013; Imianvan and Obi, 2014a; Obi, Imianvan, and Okpor, 2015; Obi and Imianvan, 2015) have used the concepts fuzzy logic to build expert systems for medical diagnosis of different ailment.

Hybrid Expert System

The Hybrid Expert System is multi-layer system that accelerates increase in performance by integrating the structures of Artificial Neural Networks and Fuzzy inference system into a single framework for solving complex problems. The hybrid model is an extremely knowledgeable system for solving the distracted equations involving the automatic knowledge expressed only by the IF-THEN rules.

According to Bekaddour and Chikh (2012), the Hybrid Expert System has strong advantages over the fuzzy expert system in the areas of automatic adaptation of the non-linear connections between inputs and outputs also it has more accurate performance.

Research scholars such as (Imianvan and Obi, 2012; Imianvan, Amadin and Obi, 2012; Obi and Imianvan, 2011; Ephzibah and Sundarapandian, 2012; Imianvan and Obi, 2011b; Obi and Imianvan, 2011d; Obi and Imianvan, 2011e; Imianvan and Obi, 2012a; Obi, Imianvan, and Ekong, 2012; Imianvan and Obi, 2012d; Imianvan and Obi, 2012b; Obi and Imianvan, 2012a; Imianvan and Obi, 2013a; Imianvan and Obi, 2014b; Obi and Imianvan, 2014b; Imianvan and Obi, 2015c; Imianvan, Obi, and Iyamu, 2015; Neshat, Yaghobi, Naghibi, and Esmaelzadeh, 2008) have also used the power of hybrid models to develop medical expert systems.

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LITERATURE REVIEW OF EXPERT SYSTEMS

This section reviewed about fifty-two (52) articles on computer based expert systems for medical diagnosis designed and developed by research scholars in the field of artificial intelligence / expert system.

Table 1 illustrates the summary of the literature reviewed in terms of techniques / methods used in designing expert system knowledge base, and the possible ailment to diagnose.

Table 1: Summary of techniques used in existing Expert System

Author	Possible Techniques				Diagnosis	Remarks
	Hybrid Approach	Non-Hybrid	Traditional Approach	Other Approach		
Imianvan and Obi (2012)	X	Fuzzy Cluster Means	X	X	Multiple Sclerosis	Intelligent
Imianvan and Obi (2012)	Neuro-Fuzzy	X	X	X	Hypotension Control	Intelligent
Imianvan, Amadin and Obi (2012)	Neuro-Fuzzy	X	X	X	Environmental Induced Depression	Intelligent
Santosh, Dipti and Indrajit (2010)	X	X	Rule-based	X	Human Disease	Not intelligent
Soltan, Rashad and El-Desouky (2013)	X	X	Rule-based	X	Angina Pectoris and Myocardial Infarction	Not intelligent
Alshaban and Taher (2009)	X	X	Rule-based	X	Human diseases	Not intelligent
Fatumo, Adetiba and Onaolapo (2013)	X	X	Rule-based (JESS)	X	Complications of Malaria and Typhoid	Not intelligent
Tunmibi, Adeniji, Aregbesola and Ayodeji (2013)	X	X	Rule-based	X	Fever	Not intelligent
Hambali, Akinyemi and Luka (2017)	X	X	Rule-based approach	X	Lassa Fever	Not intelligent
Obi and Imianvan (2011)	Neuro-Fuzzy	X	X	X	Leukemia	Intelligent
Ajenaghughrure, Sujatha and Akazue (2017)	X	Fuzzy based approach	X	X	Multi-Fever	Intelligent

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Osaseri, Onibere and Usiobiafo (2014)	X	Fuzzy Expert Model	X	X	Diagnosis of Lassa Fever	Intelligent
Ephzibah and Sundarapandian (2012)	Neuro Fuzzy System	X	X	X	Heart Disease Diagnosis	Intelligent
Hossain, Khalid, Akter, and Dey (2014)	X	X	Rule Based	X	Influenza Disease	Not Intelligent
Abdullah, Zakaria, and Mohammad (2011)	X	Fuzzy	X	X	Hypertension Disease	Intelligent
Prasad, Wood, Greer, and McCalla (1989)	X	X	X	Decision tree knowledge base	Bronchial Asthma	Not Intelligent
Bursuk, Ozkan, and Llerigelen, (1999)	X	X	Rule-based	X	Cardiological diseases	Not Intelligent
Ibrahim, Ali, Jaais, and Taib, (2001)	X	X	Rule-based	X	Diagnosis of Eye diseases	Not Intelligent
Neshat, Yaghobi, Naghibi, and Esmaelzadeh (2008)	X	Fuzzy	X	X	Liver Disorders	Intelligent
Bekaddour, and Chikh (2012)	Neuro-Fuzzy	X	X	X	Breast Cancer	Intelligent

Table 1: Summary of techniques used in existing Expert System (Continuation)

Author	**Possible Techniques**				**Diagnosis**	**Remarks**
	Hybrid Approach	Non-Hybrid	Traditional Approach	Other Approach		
Patel, Patel, and Virparia (2013)	X	X	Rule Based	X	Viral Infection	Not Intelligent
Singla (2013)	X	X	Rule-Based	X	Lung Diseases	Not Intelligent
Komal and Vijay (2014)	X	X	Rule-Based		Memory Loss	Not Intelligent
Noura (2015)	X	ANN	X	X	Heart Disease	Intelligent
Imianvan and Obi (2011a)	X	Fuzzy	X	X	Hepatitis	Intelligent

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Imianvan and Obi (2011b)	Neuro-Fuzzy	X	X	X	Bipolar Disorder	Intelligent
Ekong, Onibere, and Imianvan (2011)	X	Fuzzy	X	X	Liver diseases	Intelligent
Imianvan, Obi, and Ehigiator (2011)	X	Fuzzy	X	X	Arthritis	Intelligent
Obi and Imianvan (2011c)	X	Fuzzy Classifier	X	X	Breast Cancer	Intelligent
Obi and Imianvan (2011d)	Neuro-Fuzzy	X	X	X	Alzheimer	Intelligent
Obi and Imianvan (2011e)	Neuro-Fuzzy	X	X	X	Malaria	Intelligent
Imianvan and Obi (2011c)	X	Fuzzy Cluster	X	X	Diabetes	Intelligent
Imianvan, Anosike and Obi (2011)	X	Fuzzy Cluster	X	X	HIV	Intelligent
Imianvan and Obi (2012a)	Neuro-Fuzzy logic	X	X	X	Tuberculosis	Intelligent
Imianvan and Obi. (2012b)	X	Fuzzy Classifier	X	X	Pelvic Inflammatory Disease	Intelligent
Obi and Imianvan (2012a)	Fuzzy-Neural	X	X	X	Colon Cancer	Intelligent
Obi and Imianvan (2012b)	X	Fuzzy Classifier	X	X	Leprosy	Intelligent
Obi, Imianvan, and Ekong (2012)	Neuro-Fuzzy	X	X	X	Stroke	Intelligent
Imianvan and Obi (2012c)	X	Fuzzy Cluster	X	X	Peptic Ulcer	Intelligent
Imianvan and Obi (2012d)	Neuro Fuzzy	X	X	X	PTSD	Intelligent
Imianvan and Obi (2012b)	Neuro-Fuzzy	X	X	X	Thyroid Disorder	Intelligent
Obi and Imianvan (2013a)	X	Fuzzy classifier	X	X	Chronic obstructive pulmonary	Intelligent
Imianvan and Obi (2013a)	Neuro-Fuzzy	X	X	X	Autism Recognition	Intelligent

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Obi and Imianvan (2013b)	X	Fuzzy Classifier	X	X	Gonorrhea in Men	Intelligent
Imianvan, Ogini, and Obi (2013)	X	Fuzzy Classifier	X	X	Obsessive Compulsive Disorder	Intelligent
Imianvan and Obi (2014a),	X	Fuzzy	X	X	Enteric Fever	Intelligent
Imianvan and Obi (2014b)	Fuzzy-Genetic	X	X	X	Erectile Dysfunction	Intelligent

Table 1: Summary of techniques used in existing Expert System (Continuation)

Author	**Possible Techniques**				**Diagnosis**	**Remarks**
	Hybrid Approach	Non-Hybrid	Traditional Approach	Other Approach		
Obi and Imianvan (2014b)	Neuro-Fuzzy	X	X	X	Varied Diabetes	Intelligent
Obi, Imianvan, and Okpor (2015)	X	Fuzzy	X	X	Bacterial Wilt	Intelligent
Imianvan and Obi (2015c)	Neuro-Fuzzy	X	X	X	Varied Chicken Disease	Intelligent
Obi and Imianvan (2015)	X	Fuzzy	X	X	Cat Anal Gland Cancer	Intelligent
Imianvan, Obi, and Iyamu (2015)	Genetic-Fuzzy	X	X	X	Citrus Canker	Intelligent

EVALUATION OF EXISTING EXPERT SYSTEMS

This section tries to perform a comparative analysis / evaluation of the different possible techniques or approaches that were used in designing and developing expert systems based on the fifty two (52) research papers reviewed. Table 1 shows the statistical summary of the techniques used by the existing systems classified into two major categories i.e. intelligent and non-intelligent approaches.

Table 2: Complete Statistics of Techniques Implemented

Intelligent		Non-Intelligent Approach	
Hybrid Approach	Non-Hybrid	Traditional Approach	Other Approach
18	21	12	1

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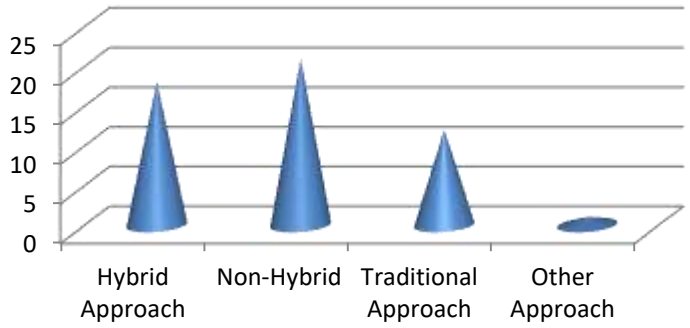

Figure 4: Graphical representation of Table 2

Figure 4 shows the graphical representation of the data gathered in Table 2 in which the Non-hybrid approach made up of fuzzy or artificial neural network system put together as the highest point, followed by the hybrid approach made up of (neural network and fuzzy system integration), followed by the traditional or classical approach (the rule-based techniques), and lastly followed by other approaches.

Table 3: Comparison of techniques

Intelligent	Non-Intelligent
39	13

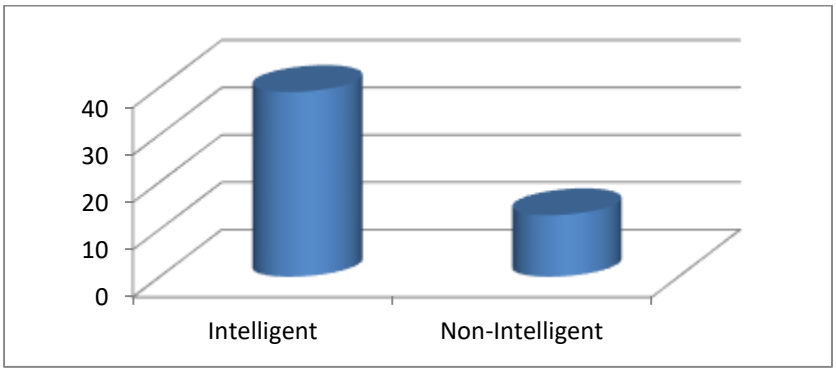

Figure 5: Graphical representation of Table 3

Figure 5 shows the graphical representation of the data gathered in Table 3. The figure tries to compare the techniques implemented in terms of intelligence. it is reveals that more research scholars supports the intelligent approach in building expert system as compared to the non-intelligent approach such as the rule-based techniques.

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FINDINGS AND DISCUSSION

This research paper reviewed fifty-two (52) articles on expert system design methodology. The authors observed from the reviewed literature that there have been positive developments on expert system for medical diagnosis based on the techniques used.

However, based on the carefully chosen benchmark for review; the following findings were perceived:

a. The existing expert system knowledge-base for medical diagnosis were built using rule-based technique, fuzzy based technique, neural network based technique and intelligent hybrid technique.
b. The rule-based techniques were seen to be inefficient based on their inability to properly learn, ineffective search strategy, and opaque relations between rules, and as such the rule-based expert systems are fast fading away.
c. The single mode intelligent models like the Fuzzy rules and Neural network rules commonly being used this days for building intelligent expert system knowledge base.
d. The intelligent hybrid expert systems for medical diagnosis can actually produce a more accurate result when compared to the single intelligent model expert system like fuzzy and neural network.

CONCLUSION

This review paper presented different expert systems for diagnosis of medical conditions associated with human health and also evaluates the methodological contributions made by the different researchers. The first set of researchers used the rule-base technique to develop their expert system; while the second set of researchers concentrated on an intelligent technique like Fuzzy Logic (FL), artificial neural network (ANN), and Genetic Algorithm (GA) to build their expert system based on the fact that the rule-based technique cannot learn properly and they might become less efficient as the production rules in the knowledge base increases. Based on our findings, there is the third set of researchers that believes in enlarging the performances of the intelligent model used by the second set of researchers to make the expert system developed more effective and efficient by combining two or more techniques together to form a hybrid model like (Neuro-fuzzy system) that can generate a more accurate results. With this conclusion, the authors has decided to recommend the usage of hybrid models for building intelligent expert systems for probing and prognosis of medical conditions.

FUTURE RESEARCH

Based on the articles reviewed and our observations / findings obtained; the author hereby recommends as follows for future research directions:

(i) Rule-based techniques should be not be used for building expert systems based on its numerous challenges.
(ii) Intelligent hybrid models should be used in building expert systems for medical diagnosis and other fault related diagnosis in machines.
(iii) Research scholars should consider using more complex integration of three models like ANN + FL + GA instead of two models for better performance and results.

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