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Evaluation of Suspected Pediatric Appendicitis with Alvarado Method Using a Computerized Intelligent Model

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Abstract

Background: Acute appendicitis is one of the common and urgent illnesses among children. Children usually are unable to help the physicians completely due to weakness in describing the medical history. Moreover, acute appendicitis overlaps with conditions of other diseases in terms of Symptoms and signs in the first hours of presentation. These conditions lead to unwanted biases as well as errors for diagnosis of acute appendicitis and increase the medical costs for hospitals and patients. The purpose of this study is to develop a computer based model in the diagnosis of Acute appendicitis specially at pediatrics field.

Materials and Methods: Fuzzy-rule based systems are popular methods widely used in the Clinical Decision Support Systems (CDSSs). In this article, a hybrid Fuzzy rule based system as a CDSS was compared with the Alvarado method for diagnosis of appendicitis in children. In this system an evolutionary algorithm was also developed to create and optimize the Fuzzy rules for diagnosis of pediatrics. To find the performance of the proposed model, a dataset was created from children with abdominal pain who referred to the teaching general hospitals in Ahvaz, Iran in 2013 to 2014 years. In this process, the results achieved from the developed model were compared with the Alvarado scoring system used for children with abdominal pain in the previous studies.

Results: The experimental results showed that the developed model has a proper performance to detect the patients with acute appendicitis from others techniques and models such as the Alvarado scoring system.

Conclusion: The developed model can be used as an assistant for physicians in the diagnosis of acute appendicitis, especially in the field of pediatrics.

Key Words**:** Appendicitis, Fuzzy logic, Meta-heuristic algorithms, Pediatric.

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1. INTRODUCTION

Clinical diagnosis is affected with various amounts of clinical symptoms, biological data and available clinical tests (1). The diagnostic challenge of some diseases is appeared when they have similar conditions in terms of symptoms, risk factors and experimental data (2). Acute appendicitis as one of the high risk acute abdomen presents the similar symptoms of other disorders (3). The risk is dramatically increased for children under six years old. Clinical decision to diagnosis of appendicitis is often made based on physicians' intuition and experience. Its overlapped symptoms lead to un-wanted biases as well as errors and medical costs for hospitals and patients. Overall, diagnostic accuracy of acute appendicitis ranges from 58% to 92% which shows the higher risk in female patients (4). Therefore, the clinical decision support systems could decrease these diagnostic errors as well as unwanted practice variation and improves the patient treatments in terms of times and costs (5). Alvarado score test as a clinical scoring system is a diagnostic tool for analyzing the signs and symptoms of acute appendicitis (16). However, inappropriate of sensitivity was demonstrated for diagnosis of appendicitis in the case of pediatrics. This method has developed in the further studies to improve the accuracy rate for detection of acute appendicitis (7-9). In recent years, Fuzzy logic has been used to model the problems with uncertainty domains for the purpose of making more accurate and real results. Fuzzy logic with using fuzzy sets defines mathematically intermediate values between crisp values such as black and white to apply human thinking way in the computer systems. Therefore, fuzzy logic can be used to formulate the imprecise problems such as decision making, classification, pattern recognition, control, and etc. Fuzzy Rule Based Systems (FRBS) are based on the IF-Then rules which contain linguistic variables to use the human knowledge in the intelligent systems. Nowadays, fuzzy logic as well as other artificial intelligence techniques, are used extensively in the Clinical decision support systems (*CDSSs*). Neural networks are the popular methods used in the clinical diagnostic systems as the learning techniques. Recently, neural networks were used in the fuzzy detection systems to assist the physicians to increase the accuracy of acute appendicitis diagnosis (1). The outcomes showed that the hybrid Fuzzy-neural networks systems can be used as an effective solution for prediction of acute appendicitis (1, 10, 11). However, current studies have still restrictions to model accurately a diagnostic system while limited clinical items and laboratory measurements are available. Moreover, many computational or optimization problems are not solved simply with using classical mathematical techniques as they need to handle a lot of complex solutions. Therefore, sometimes the results will be local optima rather than global optima (12). On the other hand, the traditional methods can be used for just a specific problem and are not enough intelligent to use in every conditions as a whole solution.

Genetic Algorithms (GAs) are a popular computational technique that follows the natural process of genetics to find the global optima solution among the huge number of solutions (13). Holland is well known to introduce and develop genetic algorithms to solve the complex problems based on the evolutionary computation (14). The idea of genetic algorithms has been captured from the Charles Darwin's theory of natural selection that creatures follow for survivals. Genetic algorithms as a popular method of evolutionary computation are used to solve the optimization problems based on the evolutionary process. Therefore, genetic algorithms with the search in the solutions space find the best or approximately results in a process of several generations (15). Nowadays, numerous applications for genetic algorithms are known in the different areas such as engineering, management, medicine, humanity sciences and computer science (16).

Recently conducted research has however simulated the honey bee offspring generation process to enhance the GAs performance for optimizing the detection problems (17). The simulated honey bee algorithm called Bees Royalty Offspring Algorithm (BROA) improves considerably, the accuracy of the classical GAs in the complicated fields (18). BROA formulates the biological process of honey bee offspring generation which leads with the Queen bee in the colony. BROA customized to use for the diagnostic system developed in this article. BROA as a meta-heuristic algorithm have the optimizing role to tune the knowledge base of the proposed fuzzy system. The meta-heuristic/fuzzy system is thus proposed to classify the patients with Right Iliac Fossa (RIF) pain into appendicitis and non-appendicitis groups. In this model, BROA was used to create the rules in order to optimize the fuzzy knowledge base. Then, the results of the diagnostic model were compared with ultrasound imaging findings to show the performance of the developed system. In the next sections the proposed hybrid model as well as its parts and performance for the purpose of acute appendicitis diagnosis are described in details.

1.1 Clinical aspects of Acute Appendicitis

Appendicitis is the most common abdominal emergency. The life-time risk of developing appendicitis is around 7% from 10 to 30 year-old patients which usually requires surgery (19). Generally, the diagnostic error in the appendectomy patients is approximately between 8% - 45% varies based on the gender (20, 21). The most important method to confirm a diagnosis of the acute appendicitis is the laboratory tests while the diagnostic sonography procedures can improve the accuracy of appendicitis prediction. Various pediatrics studies showed the sensitivity and specificity of 85-97 and 47-96 respectively, for diagnosis of acute appendicitis. There are several clinical and biochemical factors considered with the physicians to decide about patients who are suffering with the abdominal pain. Table.1 shows the most important factors usually are monitored by the doctors for diagnostic and treatment of acute appendicitis. However, high risk of infection and life lost in delayed diagnosis, variety of signs and overlapped symptoms with other diseases as well as the time consuming, high costs and variable availability of imaging procedures are the main reasons to show that computer based models may be a valuable diagnostic aid when appendicitis is suspected to be the underlying cause of an acute abdomen, particularly in low-resource countries, where imaging is not available option (2).

2. MATERIALS AND METHODS

In this research, a Hybrid Fuzzy Genetic Algorithm based model was the proposed as a differential diagnosis technique. The model was optimized while the knowledge base is created and tuned with the proposed algorithm (17). The input parameters for the proposed meta-heuristic-fuzzy classifier system are age, first abdominal pain time, initial pain site, Right Lower Quadrant (RLQ) abdomen shift, white blood cell (WBC) count and neutrophil count. Clearly, the selected features were a few of signs and symptoms showed in the (Table.1). Therefore, the proposed model was aimed to diagnose the appendicitis with a few features to decrease the limitation of children diagnosis. Overall, for the purpose of increasing the accuracy of the differential diagnosis in the appendicitis pediatric, a computer based model was developed in which a few parameters were used as the input factors. The process of classification was performed using a modified genetic algorithm simulated from honey bees mating process called Bee Royalty Offspring Algorithm (BROA), as an optimization method to fit the fuzzy knowledge with the problem conditions. Figure.1, shows the architecture of the proposed diagnostic classification system.

Table 1: Anthropometry, physical examinations and laboratory factors for diagnosing of acute appendicitis

Factors	Factors
Age	Previous surgery
Gender	Pain shift
Pain site	Foetor
Pain nature	Change of micturition
Pain time	RIF tenderness
Nausea or vomiting	Rebound tenderness
Rigidity	Guarding
Temperature	Temperature
White blood cell count (WBC)	Neutrophil count

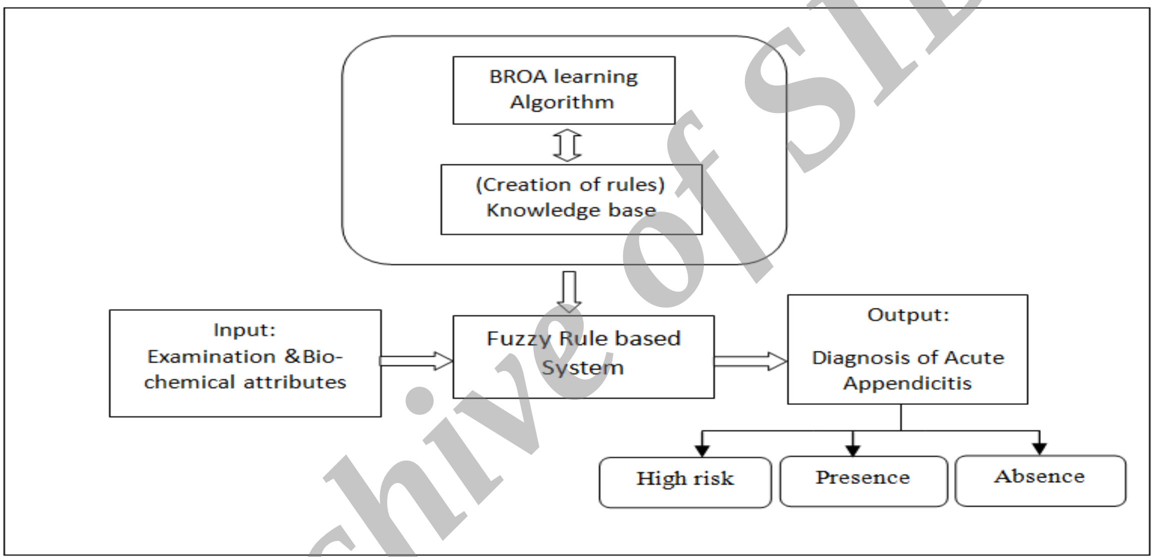

Figure 1: Architecture of the proposed differentiate diagnosis system

2-1. Abdominal data-set

To evaluate the accuracy of the proposed model for diagnosing of appendicitis, a collection of data was gathered from abdominal patients with the age under 15 years who referred to the Educational hospitals of Ahvaz, a metropolis in South West of Iran, in 2013 to 2014 years. This dataset included some features such as patient's signs and symptoms, biochemical tests as well as physicians' first diagnosis and final diagnosis about the acute appendicitis. Only 6 features were used to evaluate the reliability and validity of the model in the experimental process. Therefore, two training and testing set were randomly selected from the dataset. To show the performance of the developed model, the obtained results were compared with the outcomes achieved from the Alvarado scoring system as a popular scoring system to diagnosis of acute appendicitis.

2-2. Fuzzy Knowledge base

The computational procedure of fuzzy inference system based on the knowledge base to predict the new conclusion is implemented in the inference engine. Therefore, knowledge of fuzzy diagnostic model was determined and optimized in the knowledge base component by the BROA to find the best rules set for diagnosis of appendicitis. In this model the rules were trained to classify the input data into three classes which showed the Presence, Absence and High risk diagnostic conditions. Figure 2, shows the general frame-work of fuzzy knowledge base including rules, features (*fi*) and the acceptable values. The matrix as the input vector was optimized by the proposed meta-heuristic algorithm for diagnosis of acute-appendicitis.

$$\begin{bmatrix} if: f1=(a1)\& & f2=(b1)\& & f3=(c1)\&\cdots\& & fn=(y1)\ then\ Acute\ Appendicitis\ is\ \mathbf{Presence} \\ or & or & or & . \\ if: f1=(a2)\& & f2=(b2)\& & f3=(c2)\&\cdots\& & fn=(y2)\ then\ Acute\ Appendicitis\ is\ \mathbf{Presence} \\ \vdots & \vdots & \vdots & \vdots \\ if: f1=(am)\& & f2=(bm)\& & f3=(cm)\&\cdots\& & fn=(ym)\ then\ Acute\ Appendicitis\ is\ \mathbf{High\ Risk} \end{bmatrix}$$

Figure 2: The overall structure of Fuzzy knowledge base as the input vector of the meta-heuristic algorithm

2-3. Defuzzification

The process of converting fuzzy output values to a crisp value was determined according to the mean value of maximum (MOM) defuzzification strategy.

2-4. Meta-heuristic optimizing algorithm

For the purpose of improving the performance of the fuzzy diagnostic system, a genetic-based algorithm called BROA as a Meta-heuristic technique was used. Genetic algorithms are the popular methods to solve the optimizing problems.

In the current study, BROA was proposed to create and optimize the fuzzy knowledge base. Therefore, although the fuzzy rules are normally set by the experts, due to diversity of features as well as their effects on the diagnosis of appendicitis, the rules were created in a training process.
Moreover, the achieved results were also compared with the Alvarado findings while the data of patients with acute abdomen suspicious of acute appendicitis from hospitals in Iran were used.

2-5. Ethics

The ethics approval to conduct this research was granted by the Research Ethics and Review Committee of the Ahvaz Jundishapur University of Medical Sciences, Iran.

3. RESULTS

Table 2, shows the overall outcomes from the proposed system on the testing set. The achieved results are also compared with Alvarado test as well as other techniques in (Table3).

According to Table 2, the highest predication rate was related to the Reject status. Therefore, the model has the best performance to diagnose of the patients suffering with other diseases. However, the accuracy rate for the abdominal patients who were confirmed finally to get the appendicitis was 64%. Similarly, only 50% of the high risk patients were predicted accurately in the proper class. Overall the accuracy rate to classify the abdominal patients into three categories was around 71.4%.

Table 2: Diagnosis rate for acute appendicitis in children

Diagnostic status	Overall Accuracy rate
Presence	64%
High Risk	50%
Reject	100%
Average	71.4%

Table 3: Comparison of the diagnostic models for acute appendicitis prediction

Diagnostic model	Age category	Number of used factors	Accuracy rate
Alvarado Clinical Scoring System (ACSS) (26)	All ages	9	66.4%
Modified Alvarado System (30)	Children	Not mentioned	56%
Alvarado System (24)	Children	8	66.9%
Modified Alvarado System (25)	Children	7	64%
Multi Layer Neural Networks (27).	All ages	8	92.89%
SVM (28)	All ages	10	99%
Neural Networks (29)	All ages	10	90%
Neural Networks (26)	All ages	9	74%
Neural networks(11)	All ages	11	97%
Proposed model	Children	6	71.4%

4. DISCUSSION

According to experimental results, the average accuracy of the proposed differential diagnosis model for acute appendicitis in population was around 72 percent. The result was achieved with 6 input factors including: age range, first abdominal pain time, initial pain site, Right Lower Quadrant (RLQ) abdomen shift, white blood cell (WBC) count and neutrophil counts. To show the performance of the model, existing methods such as Alvarado scoring system were compared and considered as follows:

4-1. Alvarado Scoring System

Alvarado scoring system is widely used as a decision support system for diagnosis of acute appendicitis in recent years. Influence of Alvarado on clinical decision making in acute appendicitis was determined in several studies (22-26, 30).

In this study, the achieved results from Alvarado scoring system on suspected appendicitis in Iran was compared with the results from the proposed computer based model. Findings showed that the Modified Alvarado method has the sensitivity, specificity and overall accuracy of 53.9, 74 and 56 percent, respectively for children in Iran. The results illustrated that the Alvarado for diagnosis of pediatric appendicitis is not as reliable as diagnosis in adults (25).

Moreover, in the diagnostic process of Alvarado method more features were used as input data in comparison with the hybrid model developed in this study. According to (Table.3) the best Alvarado performance showed less than 68% of accuracy rate for diagnosis of appendicitis. Generally, the diagnosis of acute appendicitis in children population showed less accuracy rate in comparison with other age categories. Therefore, the Alvarado method showed higher error of diagnosis while needs to some input data which are difficult to determined according to children medical history. On the other hand, the proposed model in this study illustrated better performance in comparison with the current method.

4-2. Other Computer- based diagnostic techniques

According to Table.3, neural network is a popular technique to classify the presence of acute appendicitis from its absence for the data of the abdominal patients. However, neural networks needed to use large size of features including clinical and nonclinical examination factors as the input variables to show the accurate performance. Neural networks are not robust when the input factors are less than 10 features. Moreover, the Alvarado scoring system as the most cited model is not as valid as other techniques for acute appendicitis prediction (26).

On the other hand, although the Support Vector machines (SVM) showed a good performance in detection of acute appendicitis, it needs to at least 10 factors to classify the patients with acute appendicitis from non-acute appendicitis (27). The proposed model including meta-heuristic algorithm in this study resulted a performance with 90% accuracy. Although the achieved result in this study was lower than the accuracy of some algorithms used in the existing research, it used only 6 input factors for prediction. Moreover, the model analyzed the data from abdominal patients into three classes including presence and absence of acute appendicitis or high risk for acute appendicitis. Moreover, with regarding to the fact that determining larger number of the input factors needs to more laboratory tests or nonclinical examination, time costing is one of the weak points of the existing research in comparison with the proposed model. The model also showed a valuable performance in comparison with physician's primary diagnosis for acute appendicitis. According to the reported diagnosis for acute appendicitis in the dataset, the presence of acute appendicitis for 23% of patients with acute appendicitis was rejected in the primary diagnosis while the acute appendicitis was found in the final diagnosis. Therefore the primary diagnosis by physicians showed around 77% accuracy for accepting the acute appendicitis.

5. CONCLUSION

Medical diagnosis in terms of time and accuracy has the vital role to patients' life. In this study a hybrid decision support system was used to diagnosis of acute appendicitis in children. The proposed optimizing algorithm increased the accuracy of prediction with improving the knowledge base in the fuzzy rule based system. The results showed a proper performance especially in reject status of the acute appendicitis. The diagnostic acceptable performance was achieved while a limited range of factors as the input parameters were used in the hybrid model.

To compare the developed model performance, the diagnosis results from Alvarado scoring system used for suspected appendicitis in children were considered. The comparison results showed the better performance of developed hybrid model in comparison with Alvarado scoring system. Therefore, the model improves the processing time as well as the treatment costs to diagnosis of acute appendicitis in children. As a result, the computer- based model can be used as an assistant for physicians to making decision in the urgent condition for differentiate diagnosis of appendicitis in children especially conditions in which access to costly equipment such as CT scans and sonography tools are limited.

6- CONFLICT OF INTEREST: None.

7-ACKNOWLEDGMENT

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