



Research Article

An Expert System for Assistance in Human Intestinal Parasitosis Diagnosis

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Citation: Nkamgang OT, Tchiotso D, Fotsin HB, Talla PK (2018) An Expert System for Assistance in Human Intestinal Parasitosis Diagnosis. Biosens Bioelectron Open Acc: BBOA-128. DOI: 10.29011/2577-2260.100028

Received Date: 14 March, 2018; Accepted Date: 12 April, 2018; Published Date: 19 April, 2018

Abstract

Purpose: The diagnosis of intestinal parasitosis diseases relies on physiological symptoms and stools exam. Specialist physician are not enough and the stools exam manually done is slow, prone to error and not without negative effect on the eyes of laboratory assistant. We aim to design and implement a medical expert system helper for the diagnosis of human intestinal parasitosis diseases.

Methods: The system follows a decision algorithm. The knowledge base was constructed through information coming from books and physician in charge of those diseases. The user interacts with the system by answering questions. Symptoms collected conduct to microscopic exam of stools run by the system with a priori suspected parasites. The automated microscopic exam of stools consists of a combined distance regularized level set evolution automatically initialized by circular Hough transform and a trained neuro-fuzzy classifier. The neuro-fuzzy classifier was trained for twenty human intestinal parasites considering noise and rotation.

Results: we have integrated the reasoning scheme of diagnosis and automated clinical exam of stools in the same system. The parasites found in microscopic image confirm the suspicious disease. The final recommendation of diagnosis is completed with proposed appropriate therapy. We have evaluated our system on sixty case of infection with the diagnosis of two doctors and have obtained fifty eight correct diagnosis corresponding rate.

Conclusions: The proposed system is automatic since the parameters of segmentation, features extraction and classification are set automatically guided by the type of suspicious parasite seek in the microscopic image. This is a notable contribution to medical healthcare assistance.

Keywords: Classification; Expert System; Intestinal Parasites; Microscopic Image; Segmentation

Introduction

Human intestinal parasitic diseases are part of neglected tropical diseases causing illness and death. The lack of hospitals and clinicians is a great barrier for population to have an appropriate medical care. In other hand, the diagnostic that relies on microscopic images analysis is done manually in medical laboratories. Thus,

the production of results is slow, prone to errors and not without negative effect on laboratory assistant eyes. Several studies have been carried out in other to assist doctors in medical diagnosis task. MYCIN [1] was an expert system for the diagnosis bacterial infectious diseases of blood. It was the first with separating the inference engine well from the knowledge base and being able to explain it reasoning. However, its rules were affected coefficients of probability. To each rule was assigned a particular weight. The engine produced was a simple forward chaining calculating the

probabilities of each deduction. The system was unable to explain the logic of its operation and to detect contradictions. Windyga et al. [2] presented an expert system named SETA developed for the management of patients in coronary or cardiac care units. The system was constructed on the multiknowledge base architecture using a PC-compatible expert system development shell named M.1 as a development tool of rules production. M.1 provided to SETA a facilities explanation capability. Each knowledge base follows particular arrhythmia and relevant complication. The system suggests therapeutic actions for the treatment of serious arrhythmias while taking into consideration aspects that are very important for the human expert. The system was not designed for real-time operation. Santosh et al. [3] proposed a diagnosis expert system for the medical consultations following fast questionnaire and offers in addition the explanations aspect. The system is based on a symbolic inference engine handling whole rules and thus requires a transcription of the characteristics and symptoms of the disease to that standard symbolic system. It thus returns the problems of the reliability of the data which entered there. Soundararajan et al. [4] presented a knowledge based system for tuberculosis. The system was developed using fuzzy logic for class assignment process and rule-based fuzzy diagnostics decision support system to assign class labels for tuberculosis. Authors come up with 16 rules for conditions and 323 sets of rules for the determination of the class of tuberculosis. The system evaluated the level of risk of tuberculosis patient with received symptoms. The system could not run clinical exam. Fatumo et al. [5] designed and implemented a medical diagnostic expert system for the various kinds of malaria and typhoid complications named XpertMalTyph. The system is based on JESS (Java Expert System Shell) programming. Java programming language was used as the implementation tool and its java server page makes the expert system a web-based application. The database engine used was MySQL integrated with JESS. The various modules used have been integrated from a single web interface. Soltan et al. [6] proposed a medical expert system for heart diseases. The proposed system was constructed in Visual Prolog 7.3. The symptoms of the patients are introduced by answering question through user interface. The system then deduced a diagnosis and proposed a treatment. The system was focalized on two heart diseases named angina pectoris and Infarction.

A collaborative software agent's framework was presented by Octavian et al. [7] to simplify the information exchange within the medical diagnosis process. The system was based on knowledge management, Bayesian Network for uncertainty reasoning and software agents. The system only deals with information sharing and could not analyze or use them for diagnosis. Mohktar et al. [8] have developed a rule base expert system to classify the total level of Cholesterol level in body. Authors used bioelectrical impedance analysis. The study was investigated on 199 voluntary subjects.

The expert system was able to correctly classify 6 from 10 subjects which mean 0.6 probability accuracy for classifying TC level. No clinical exam could be carried by the system. The expert system presented in [9] assist doctors, nurses, and students in orthopedic diseases diagnosis. The system provides a repository of information vis-à-vis multiple diseases. The system was constructed using ES_Buider 3.0. ES_Buider 3.0 is a tool of expert system 'shell' that allows generating decision tree and incorporating expert knowledge. It generates user interface and built exporting function for web page creation. The authors obtain from expert system information similar to skilled doctor in the domain. The system cannot run a test and only analyses information from answered questions. A review of others thirteen medical expert systems for diagnosis of various diseases have been carried out in [10]. Authors presented for each expert system the diagnosed disease, the technique used, input and remarks. Knowledge Based System and Rule based Expert System are the recurrently used. Those systems received symptoms or results of clinical exams as input to infer diagnostic. The average good results of diagnostic show that expert system could improve various domain of healthcare. None have been devoted to human intestinal parasitic diseases.

In this paper, we present an expert system helper for the diagnosis of human intestinal parasitosis diseases. At our knowledge, no expert system has been devoted to diagnosis of human intestinal parasitosis. The system integrates the artificial reasoning and the automatic stools exam. This stools exam is automatic since parameters of parasite detection and recognition are set automatically according to suspicious parasites. The system follows a decision algorithm to proposed diagnosis and appropriate therapy.

The remainder of this paper is organized as follows: Section II presents materials and methods. In Section III, we present some results. We close with a conclusion.

Materials and Methods

Materials

The proposed expert system is implemented on a HP Elite book 6930p with Intel(R) core (TM) 2 Duo CPU, 2.53 GHz, 2 Go RAM, with MATLAB 2014a, on Windows 7. The knowledge base includes rules and facts obtained from books [11,12] and local doctors. The automated exam of stools includes a pre-process, a segmentation process and a classification process. We have trained a neuro-fuzzy classifier with twenty classes of recurrent parasite. We have constructed a data base of microscopic images gleaned from web-sites [13-15]. We firstly obtained a data base of 1240 originals images. In order to increase the size of our database of images, we have added 'gaussian', 'poisson', 'salt & pepper' and 'speckle' noise to each image. We have also rotated each image with angle of 30°, 60°, 90°, 120° and 150°. A number of 560 new images have then been

added to the original database. We have obtained a comfortable database of 1800 microscopic images corresponding to 90 specimens for each of the twenty classes.

The Expert System

The proposed expert system architecture as presented in figure 1 involves the knowledge base, the decision algorithm, the explanation mechanism and the user interface. It presents the flow of information exchange between the system and its surroundings: firstly, with knowledge engineer which collects rules and facts from doctors and books to feed the knowledge base of the system, secondly with the user from whom it receives symptoms and proposed a diagnostic.

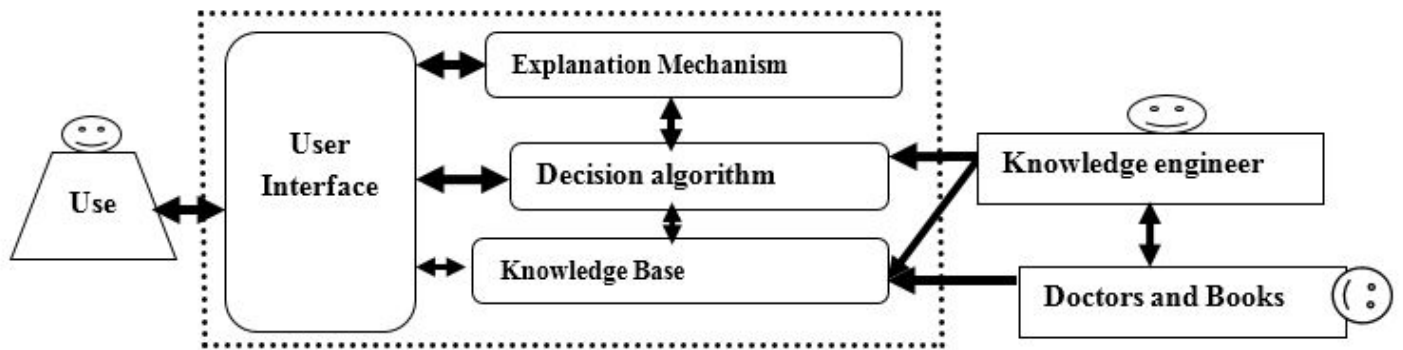


Figure 1: The proposed expert systems architecture presenting the flowing exchange of information in the system and between the system with its surroundings.

User Interface: The user interface allows communication between the user and the system. It takes input to the system (symptoms or signs), and presents output to the user such as diagnosis results, explanation, treatment details and recommendations. Symptoms and signs of diseases collected conduct to suspicious parasite. We have proposed an automated exam of stools based on detection and recognition of intestinal parasites in microscopic images. The method consists of segmentation and recognition.

Segmentation: The edge map of the original image is firstly detected by canny edge detector. The detection and extraction of the parasites are done by Distance Regularized Level Set Evolution (DRLSE) initialized by Circular Hough Transform (CHT). Many of intestinal parasites are ovoid and their shape in the image can be approximated to circles. According to the circle equation (1), each edge pixel (x, y) contributes a circle of radius R to an output accumulator space.

$$(x - x_a)^2 + (y - y_a)^2 = R^2 \quad (1)$$

Where (x_a, y_a) are center pixel coordinates and R the radius of the circle.

The output accumulator space has a peak where these contributed circles overlap at the center of the original circle.

The center pixel (x_a, y_a) and the radius (R) parameters for

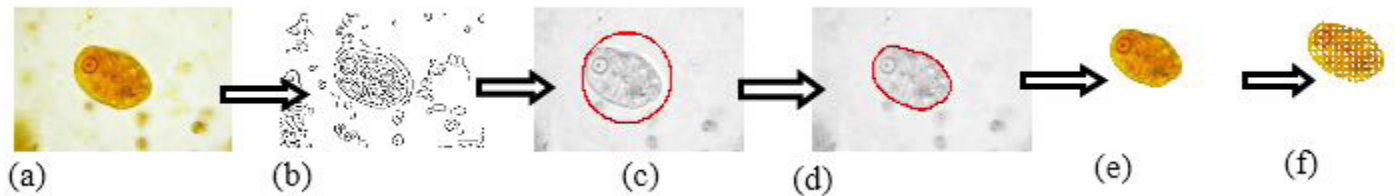
the accumulator with the highest vote are used to draw the corresponding circle on original image. The drawn circle is used as initial function of DRLSE. The partial differential equation of the level set evolution is given by equation (2).

$$\partial f / \partial t = m \operatorname{div}(d_p(|\nabla f|) \nabla f) - \partial x_{\text{ext}} / \partial f \quad (2)$$

Where f is the level set function, m is the distance regularization coefficient of level set function control and $x_{\text{ext}}(f)$ the energy function. DRLSE aims to minimize the energy function

$x_{\text{ext}}(f)$. To satisfy this constraint, the level set function evolves until accurately fit the parasite boundary. The final level set function is a signed distance function which value is positive inside and negative outside. The extraction process consists of looking the corresponding pixel in original image with final negative level set function values and set them to white color. This method is fast and less memory consuming compared to the method used by SAHA et al. [16]. As result, we have an image of the parasite alone with white background which is proper for features extraction. Figure 2 illustrates DRLSE automatically initialized using circular Hough transform which constitutes the segmentation process of our automated stools exam. We firstly converted the microscopic images to edge maps using canny algorithm (figure 2b). Next, we located the parasite through circular Hough transform and draw circles around them (figure 2c). Those circles stand as initial

contours of DRLSE. The contours evolve until they fit the boundaries of the parasites (figure 2d) despite fecal debris around it here consider as noise. The final extraction is performed using a complementary method based on the signed distance character of the level set function. As result, we have an image where only appear the extracted parasite with white background (figure 2e). It is then easy to extract features characteristic of the parasites for its recognition.



Figures 2(a-f): Extraction process: (a) original image with *Entamoeba histolytica* trophozoite, (b) edge map (c) the parasite located, (d) the parasite detected, (e) the extracted parasite and (f) visualization of histogram oriented gradient features grid locations.

Classification: We extracted features from the extracted parasite using histogram-oriented gradient. The visualization of Histogram Oriented Gradient (HOG) features grid locations is presented at figure 2f. At each pixel, the image gradient vector is calculated. So, being given an image I , we obtain the x and y derivatives using a convolution operation: $I_x = I \cdot D_x$ and $I_y = I \cdot D_y$. The magnitude (G) and the orientation (J) of the gradient are given by equation (3):

$$|G| = \sqrt{I_x^2 + I_y^2}, \quad J = \arctan(I_y / I_x) \quad (3)$$

We obtained feature vector to the order of thousand in dimension. This is too high to be directly use by a classifier. The dimension of the feature vector is reduced by Linear Discriminant Analysis (LDA). LDA find a subspace which gathers the samples from the same class and meanwhile enlarges the margin of samples from different classes. Mathematically, this objective is achieved by maximizing the Fisher criterion (the ratio of the between class scatter to the within class scatter (equation (5))).

$$J = \frac{|w^T s_b w|}{|w^T s_w w|} \quad (5)$$

Those features are introduced in a trained neuro-fuzzy classifier for the recognition of the parasite. It consists to determine the optimum parameters $\mathbf{q} = \{S_{M \times N}, \Gamma_{M \times N}, W_{M \times O}\}$ of the fuzzy if-then rules from the cost function $E(\mathbf{q})$. S and Γ are the matrices containing the width (s) and the center (c) values of the membership functions respectively; W is the weight matrix of connections from fuzzification layer to defuzzification layer. M , N and O are respectively the number of rules, features, and classes.

The neuro-fuzzy classifier was trained for twenty intestinal parasites (Protozoa and Helminths) in various stages (cyst, egg and trophozoite). We have used a constructed data base of 1800 microscopic images corresponding to 90 specimens of each type of parasite. The rotation of the parasite and noise in image was taken into account. The extracted microscopic image of each parasite is presented in figure 3. From the extracted parasite, we extracted features using histogram-oriented gradient. Afterwards most significant and non-redundant features are selected using LDA. Those features are used by the NFC for the classification of parasite.

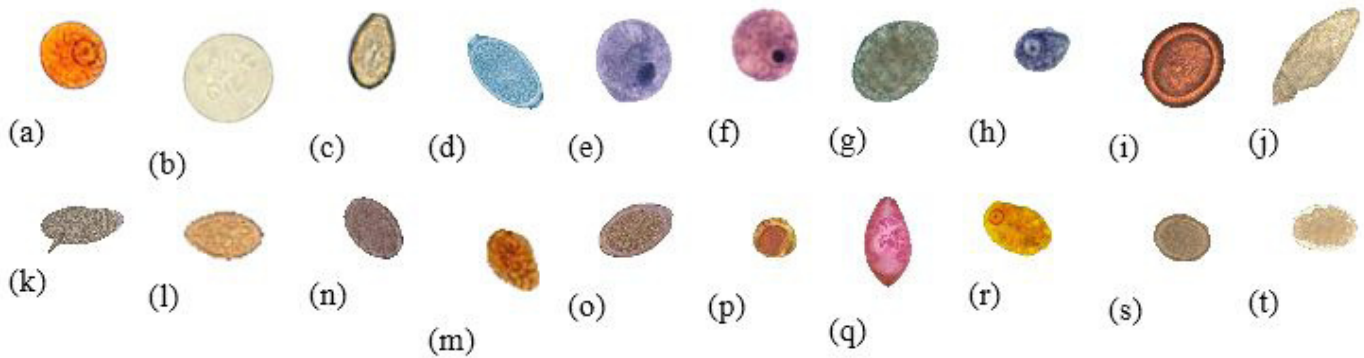


Figure 3: Extracted microscopic images of parasites. (a) *Entamoeba histolytica* cyst, (b) *Entamoeba coli* cyst, (c) *Clonorchis sinensis* egg, (d) *Trichuris trichura* egg, (e) *Balantidium coli* cyst, (f) *Iodamoeba butschlii* trophozoite, (g) *Diphyllobothrium latum* egg, (h) *Chilomastix mesnili* cyst, (i) *Hymenolepis nana* egg, (j) *Schistosoma mansoni* egg, (k) *Schistosoma haematobium* egg, (l) *Heterophyes heterophyes* egg, (m) *Giardia lamblia* Cyst, (n) *Fasciola hepatica* egg, (o) *Blastocystis hominis* egg, (p) *Paragonimus westermani* egg, (q) *Entamoeba histolytica* trophozoite, (s) *Taenia solium* egg and (t) *Ancylostoma duodenale* egg.

The Knowledge Base: The knowledge base is the heart of the expert system. It is the collection of facts and rules which describe all the knowledge about problem domain. It takes a collection of relevant knowledge that is stored in a computer and organizes the information in such a way that it can be used by the decision algorithm. These rules are in the form of IF-THEN that make use of various tests in or out a diagnosis. These tests are scheduled based on suspicion of disease. These rules were implemented according to information collected from local doctors and books. Our knowledge base integrates 82 (eighty-two) facts: 18 (eighteen) diseases (Table 1) and 64 (sixty-four) symptoms (Table 2). They are declared in the forms of:

Disease 1: Ascariasis	Disease 10: Ankylostomose
Disease 2: Lambliasis or gardiasis	Disease 11: Clonorchiasis
Disease 3: Banlantidosis	▪ Disease 12: Trichocephalosis
Disease 4: Taeniasis	Disease 13: Fasciolosis or hepatic distomatosis
Disease 5: Blastocystosis	Disease 14: Isosporosis or Coccidiosis
Disease 6: Amoebiasis	Disease 15: Paragonimiasis or pulmonary distomatosis
Disease 7: Pulmonary distomatosis	Disease 16: Diphyllbothriosis
Disease 8: Intestinal distomatosis	Disease 17: Infantile Téniasis
Disease 9: Ancylostomiasis	Disease 18: Bilharziosis or Schistosomiase

Table 1: Diseases in charge of the designed expert system.

The symptoms and signs of those diseases have also been declared as presented in table 2.

Symptom 1: diarrhea
Symptom 2: headache
Symptom 3: fever
Symptom 4: stomach bloating
Symptom 5: dry cough
Symptom 6: anorexia
Symptom 7: bulimi
Symptom 8: vomiting
Symptom 9: nausea etc...

Table 2: Some examples of symptoms of the knowledge base.

We have constructed a rule base of 186 rules. Each rule is stated in the form of: If patient have symptom1 and symptom 2 and symptom 3 and symptom 4 and parasite found in stools is parasite x then Disease is Disease x.

For example, we have:

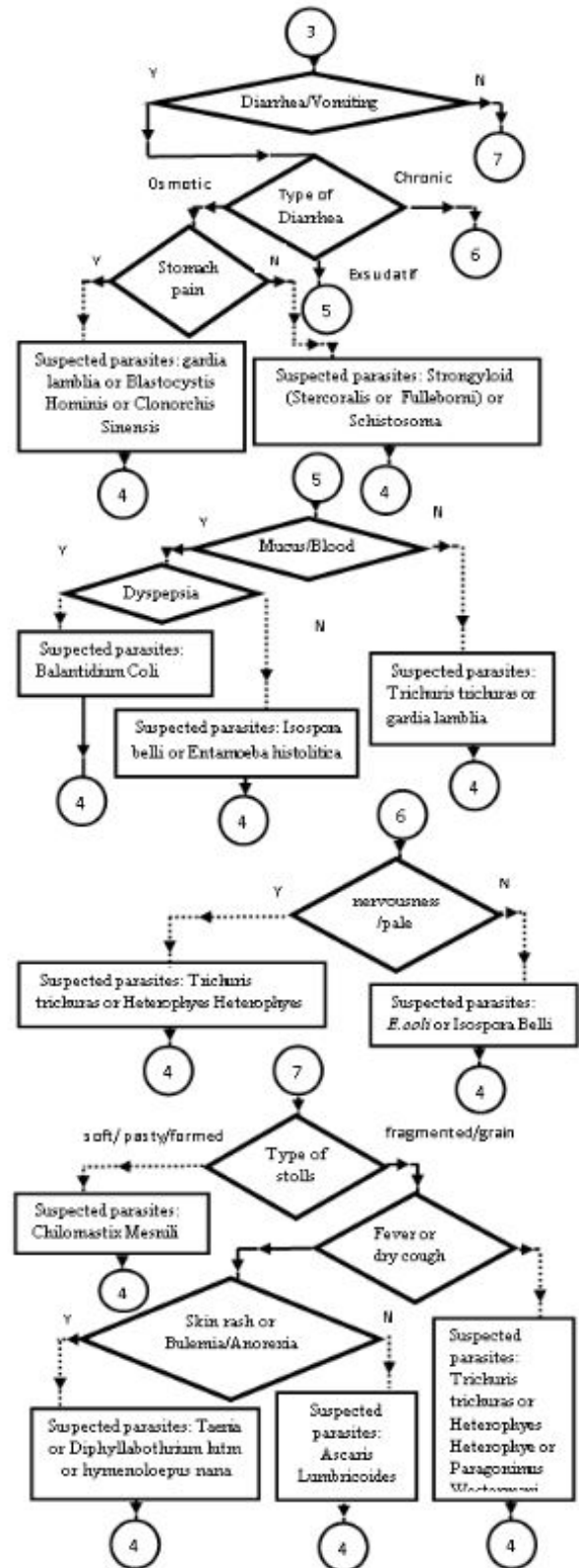
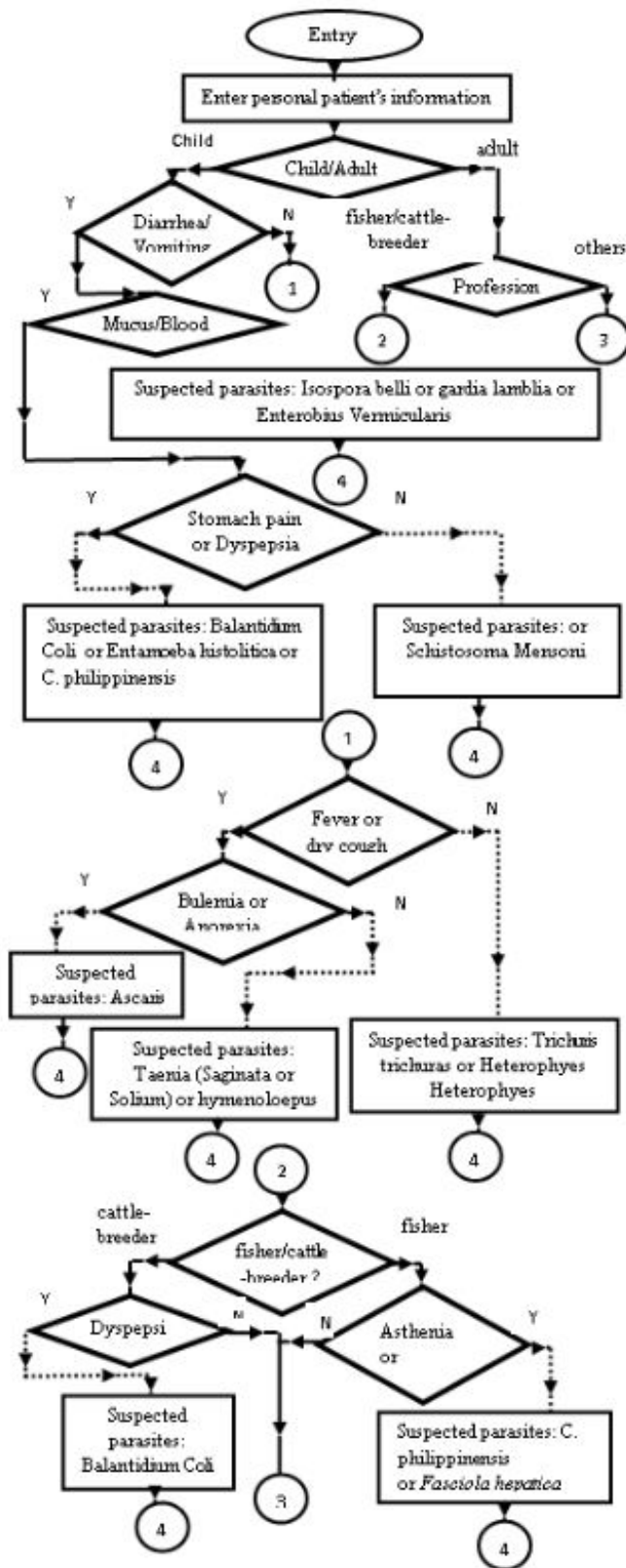
- If patient have chronic diarrhea and fever and stomach bloating or duodenitis and nausea and parasite found in stools is *Giardia intestinalis* or *lamblia* then Disease is Lambliasis or gardiasis.
- If patient have fever around 38°C and dry cough and dyspnoea and vomiting and nausea and parasite found in stools is *Ascaris lumbricoides* in stools, then Disease is Ascariasis.
- If patient have diarrhea with blood or mucus and moderated or oscillating fever and stomach pain and parasite found in stools

is *Entamoeba histolytica* then Disease is Amoebiasis.

- If patient have abdominal pain and nausea and bulimia or anorexia and ocular or neurological trouble and parasite found in stools is *Taenia solium* or *saginata* then Disease is Taeniasis.
- If Disease is Lambliasis or giardiasis, then proposed therapy is FLAGYL® (metronidazole) 10 mg/kg/day in 2 doses during one week.
- If Disease is Amoebiasis then proposed therapy is INTETRIX® (tibroquinol ettiliquinol) 2 g per day during 6 days or FLAGYL® (métronidazole) 2g per day during 7 days.
- If Disease is Ascariasis then proposed therapy is FLUVERMAL® (flubendazole) 200mg per day during 3 days or ZENTEL® (albendazole) 200mg in 1 dose for less than 2 years' child, 400 mg in 1 dose for above 2 years.

COMBANTRIN® or HELMINTOX® (pamoate de pyrantel) 12,5mg/kg in one dose.

The Decision Algorithm: The decision of our proposed system is guided by a forward chaining algorithm. The goal of the decision algorithm is to deduce facts. Consequences are deduced from the initial facts present at the beginning in the knowledge base. For that purpose, it will traverse the knowledge base; it will examine the facts one by one and, regarding them as fact-conditions, it will seek in the left part of each rule if there is correspondence between one of the condition-premises of the rule and the fact considered. The decision algorithm thus explores all the rules contained in the knowledge base, seeking for each one of them to start its consequence. We have implemented the decision algorithm of the proposed expert system in MATLAB. It follows the flow chart presented in figure 4 which consists of successive test depending of received answers.



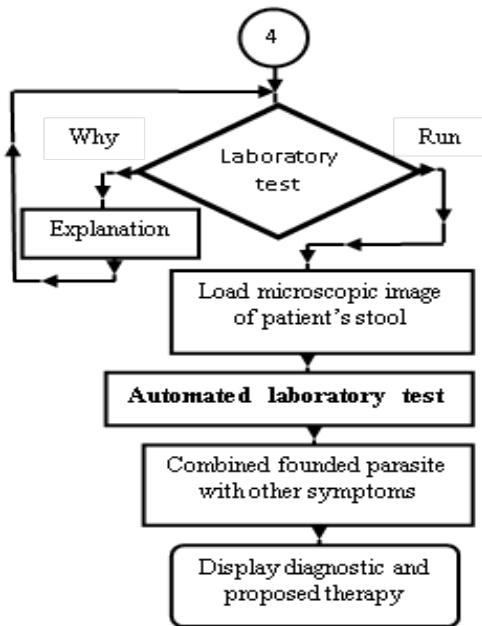


Figure 4: The decision algorithm flow chart of the proposed expert system illustrating tests involve in the reasoning scheme.

It is completed with the flow chart of the automated stools exam of figure 5 involving the segmentation of the microscopic images of stools of the patient and the recognition of the detected parasite. Given a database of true facts, all rules that match facts in the database are successively applied. The conclusion is added to database. This is repeated until deduced suspicious parasites or new fact or required others expertise. The interrupts paths indicate that others symptoms can be taken in account. Suspicious parasites are founded in microscopic image of stools during automated laboratory test. Their recognition is combined with symptoms to produce a diagnostic.

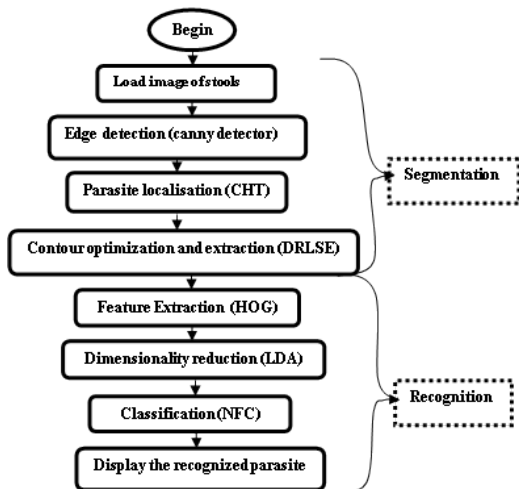
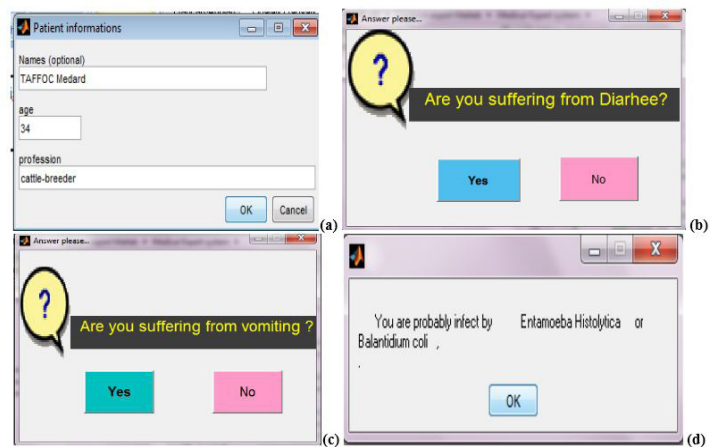


Figure 5: The automated laboratory test flow chart of the detection of

human intestinal parasite, it extraction from microscopic of stools and it recognition.

Experimental Results

Assuming the expert system acts as a physician for a patient, the user will have answered a few questions about the patient's conditions. The system begins by general questions and is guided by answers to suspicious parasites. Figures 6(a, b, c) presented a sample of questions asked to the user. The user answers question by filling provided space or clicking on button 'yes' or 'no'. Questions successively present are oriented by the decision algorithm according to answers and conducted to suspicious parasite (Figure 6(d)).



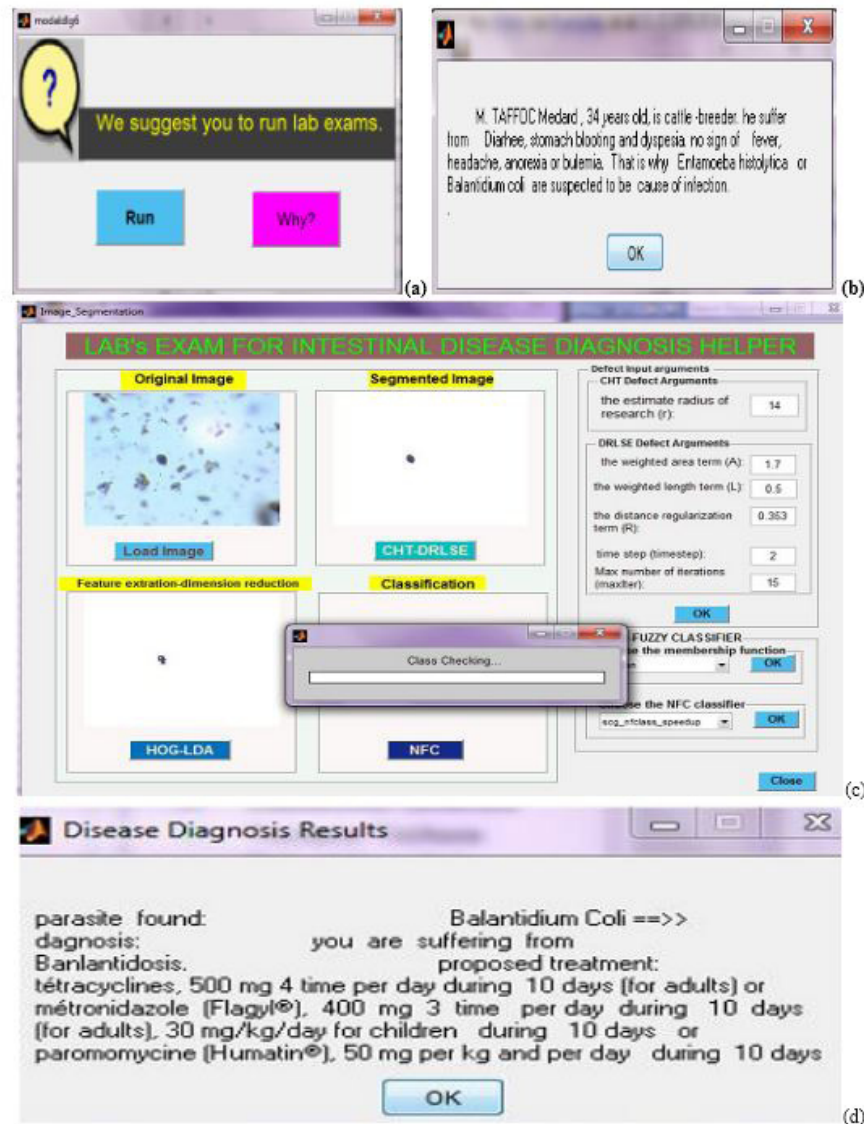
Figures 6(a-d): User interface. (a), (b) and (c) dialog for information collection, (d) suspicious parasites.

In figure 7(a), we presented the dialog interface of the system proposing to run a stools exam. If the user clicks on "why" button, an explanation of the deduction is given (Figure 7(b)). The suspicious parasite responsible of health trouble are confirmed or infirmed by the exam of stools. Figure 7(c) presented the interface of automatic exam of stools. After load microscopic image of stools of the patient using the button "load image", the user will successively click on "CHT-DRLSE", "HOG-LDA" and "NFC". The system will process the segmentation and the recognition of the detected parasite. The proposed scheme of segmentation was applied on our data base of microscopic images with various kind of parasite. Results show how accurate and less time consuming the method is. The parameters of research are set automatically according to suspicious parasite. The user can also set those parameters for a particular research and the system will learn from new conclusion. Those parameters are accessible at the right side of interface presented in figure 7(c). They are: the estimated radius

of research for Hough transforms, the weighted area term $A_g(\mathbf{f})$

, the coefficient of the distance regularization term $R_p(\mathbf{f})$, time

step *tstep*, the coefficient of the weighted length term $L_g(\mathbf{f})$ and the maximum number of iterations for DRLSE. This opens the field to enlarge the research of new parasite. The images of database were divided in two set for training and testing phase. The results show a perfect classification of twenty intestinal parasites (Protozoa and Helminths) in various stages (cyst, egg and trophozoite). The twenty classes of parasites were perfectly classified while testing the trained neuro-fuzzy system. The recognized parasite is combined with others symptoms for the diagnosis of disease and a therapy is proposed (figure 7(d)). The system was trained to recognized twenty parasites independently of their stage of evolution. Thus, corresponding diseases are also well diagnosed. It is worth to mention that the diagnosis and therapy are only a recommendation for user and physician non expert in domain.



Figures 7(a-d): User interface. (a) Dialogue proposing to run stools exam (b) recalling information for explanation (c) The automatic exam of stools interface (d) diagnostic result and a proposed therapy.

We have simulated the execution of our system on sixty case of infection. Questions asked by the proposed system with corresponding answers of patient were presented to two doctors. Images were picked in a data base of 210 microscopic images. The system obtained fifty-eight correct diagnoses concordant to the same decision of the two doctors. This corresponds to a correct diagnosis

rate of 96.6%. The corresponding therapies for each diagnosis were also approved. In the two others case, the two doctors and the proposed diagnosis system were not in accordance. The system still has problem with contradiction. For example, when the suspicious parasite is not found in loaded microscopic image of stools or another parasite different from suspicious is found. The knowledge base of the system could then be increase with facts and rules. The trained neuro-fuzzy classifier can also been update with new type of parasite for more recognition.

Conclusion

We have presented in this work a medical expert system helper in the diagnosis human intestinal parasitosis diseases. The system is made around a decision algorithm which used the constructed knowledge base and user answers to proposed diagnosis and appropriate treatment. The user interacts with the system by answering question. When necessary, automated microscopic exam of stools is proposed and run by the system. This is done by a combined distance regularized level set evolution automatically initialized by circular Hough transform and a trained neuro-fuzzy classifier. The parameters of segmentation, features extraction and classification are set automatically guided by the type of suspicious parasite seek in the microscopic image. The user is only called to load a microscopic image of stools of the patient. The final recommendation of diagnosis is completed with proposed appropriate therapy. We have evaluated of our system on sixty case of infection with the diagnosis of two doctors and have obtained fifty eight correct diagnosis corresponding 96.6% rate. The proposed expert system is a notable contribution in medical diagnosis assistance.

Acknowledgements

The authors wish to thank the laboratory assistant TAFFOC Guy Aimé and collaborators of regional hospital of Bafoussam (western Cameroon) for their invaluable support and knowledge sharing.

Compliance with Ethical Standards

Formatting of Funding Sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of Interest

None declared.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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