Online Medical Assistant (OMA): A Dynamic Collaborative Web-based Medical Decision-Support Intelligent System

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Abstract: *The Online Medical Assistant (OMA) is a dynamic collaborative web-based medical decision-support expert system in which medical self-diagnosis expert systems are integrated inside as medical engines which respectively focus on different medical domains, and the portal of the system plays the role of a coordinator which merges the web pages, medical engines and all kinds of application programming interfaces (API) into one web-based system. The Development of such kind of web-based medical decision-support expert system is not intended to replace the role of physicians in the diagnostic inference process, but to be a decision-support assistant for the physicians and medical experts in the procedures of diagnostic reasoning.*

Keywords: Fuzzy Logic, Decision-Support systems, Medical Expert Systems, Acute Abdominal Pains, Self-learning, Self-growing, Self-diagnosis Medical systems, Medical Knowledge Base.

1. Introduction

The diagnostic reasoning procedure of a physician is to find out a list of diagnostic possibilities for the patient based on the presented symptoms. To master this process he had to study many relationships of obligatory or facultative proving or excluding symptoms for diagnosis in books and journals and in his practical experience. But all of these efforts can not guarantee the diagnostic accuracy.

For instance in the field of Acute abdominal pain (AAP) which is the most common surgical emergency. Although AAP is a common problem, diagnosis, particularly in the early stages of presentation, it is often difficult and only around 50% of patients are correctly diagnosed when first presenting to hospital. This leads to unnecessary admissions, investigations and interventions. The introduction of new technologies and investigations, such as ultrasound and CRP, has not significantly improved this situation. The negative appendectomy rate is still between 20 to 30% and as high as 50% in young women. [1] What makes the diagnosis of AAP particularly difficult is the fact that many acute abdominal pains show a large overlap in terms of their symptoms, e.g. the causes of abdominal pain with vomiting and jaundice include: Acute Pancreatitis; Cholecystitis; Gallstones; Pancreatic cancer; Stomach cancer and so on. [2]

This situation could be improved by the standardization of the methods for the acquisition of the medical history and examinations, and with the help of computer aided diagnostic systems which named medical expert systems. [3] The most important ingredient in any medical expert system is the medical knowledge bases, as the power of medical expert systems resides in the specific, high-quality knowledge they contain in certain domains.

Medical knowledge bases contain the information about relationships that exist between symptoms and symptoms, symptoms and diagnoses, diagnoses and diagnoses, more complex relationships of combinations of symptoms and diagnoses to a symptom or diagnosis. The knowledge bases are difficult to be improved, because the effort from a few professionals is obviously not enough. For most diagnosis expert systems, it takes many years to develop but still not walk out the laboratory. [4] Due to this fact, nowadays more and more medical experts and software engineers are working together to develop the web-based medical expert systems, as such kind of system provides the possibility to allow the developers from all over the world to take part in the construction of medical knowledge bases and the development of the system.

Our medical decision-support expert system "Online Medical Assistant" is such a web-based medical expert system which supports even the normal patient users to take part in the construction of the system. The development of such a dynamic collaborative web-based medical decision-support expert system is totally a new idea, as it not only allows the user to make online medical self-diagnosis, to communicate with medial experts and web developers, the users can even take part in the construction of the medical knowledge bases of the medical engines which focus on different medical domains. The portal of the system is used as the console for the developers, e.g. the medical experts and the software engineers, to cooperate with each other, and the medical knowledge attributes and settings of the medical engines can be modified by the developers just in the browser instead of editing the source code line by line on the server side. Upon the flexible structure of the "Online Medical Assistant", the accuracy of medical diagnosis is expected to be enhanced remarkably.

The main features of Online Medical Assistant can be summarized as follows:

Flexible: All the settings and attributes of the medical engines which are integrated inside the system can be directly modified in the browser. After the developers trigger the event of "Update System" (click the button of "Update System" in the corresponding web page), then the whole system will be updated immediately.

Robust: The medial engines in the system are developed based on fuzzy logic so that these engines can work on the imprecise, incomplete patient data. In the standard web-based patient data questionnaire, the option of "Ignore this Question" is implemented which is used to pass the questions which the patient users are not sure.

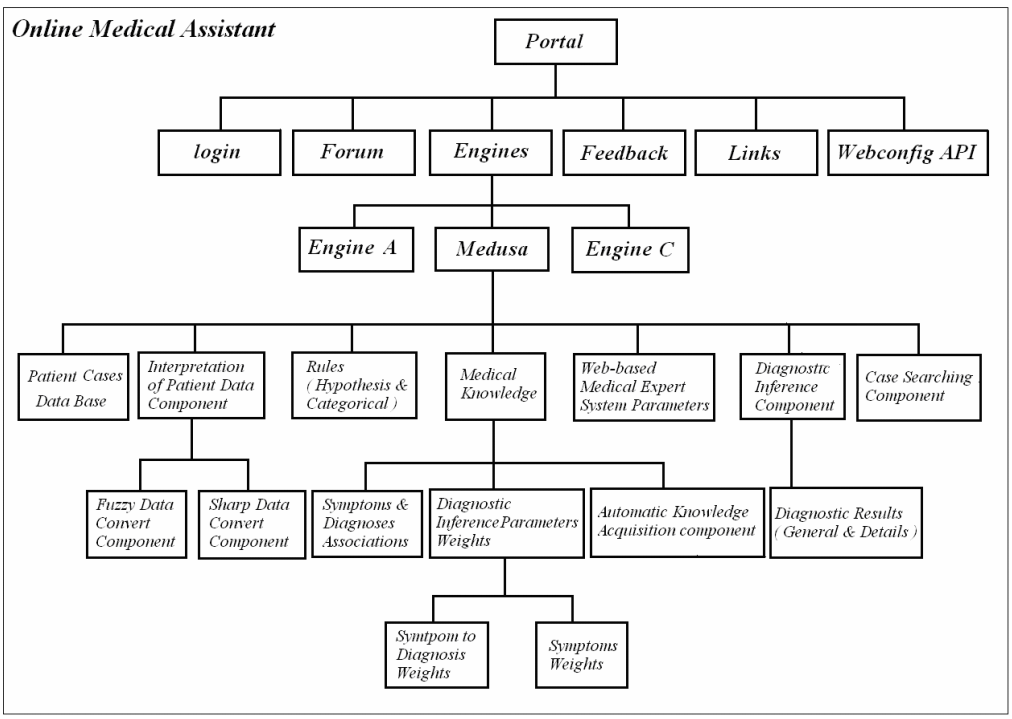

Figure 1: The Framework of Online Medical Assistant

The diagnostic inference component of the system only works on the symptoms the users have answered unambiguously, and then converts these linguistic patient data into the corresponding numeric symbols which the computer can recognize. The more symptom questions the users answer, the more medical factors will be considered into the heuristic reasoning by the diagnostic inference component of the medical engines, so that the accuracy of the final diagnostic inference results will be enhanced correspondingly.

Self-growing: Just in the browser, the patient users can submit his or her personal patient cases to the system with their final official discharge diagnosis acquired from hospitals or other medical institutes. These patient cases can be loaded into the medical knowledge base of the corresponding medical engines and used as reference cases under the agreement of the administrator.

Self-learning: The intermediate data and tables which the heuristic reasoning is based on can be refreshed and recreated automatically by the automatic knowledge acquisition component of the medical engines whenever their medical knowledge settings are modified by the medical experts or other developers.

2 Medical Engine (MEDUSA)

2.1 Overview

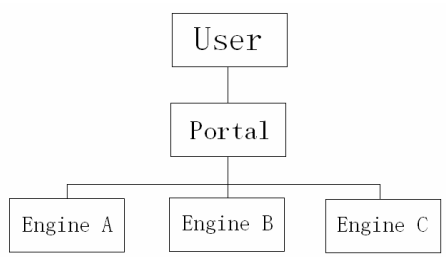

Figure 2: Online Medical Assistant

The OMA is composed of several medical engines which are integrated inside the system and coupled with each other by the portal as showed in Figure 2.

The medical expert system MEDUSA is such a medical engine which is a decision-support expert system for the diagnosis of Acute Abdominal Pains (AAP). The system is intended to be an active assistant for the physician in diagnostic situations and helps the physician with diagnosis and therapy by providing diagnostic proposals and explanations. The main features of MEDUSA are listed as follows.

1) MEDUSA is based on fuzzy logic, which means the system uses fuzzy sets and fuzzy relations to realize the representation and application of uncertain and imprecise knowledge so that the inexact medical entities can be modelled by fuzzy sets and the uncertain medical associations can be modelled by fuzzy relations. [5][6] In addition, fuzzy logic enables the formal treatment of making approximated inferences on the basis of fuzzy data and fuzzy relations.

2) MEDUSA possesses an automatic knowledge acquisition component which starts from a given case database, automatically computes the relations between the medical entities contained in the patient cases database.

3) MEDUSA has over 60 rules and 4000 fuzzy relations. Its patient case database consists of 1256 cases. The diagnostic inference process is based on about 200 symptoms.

4) The main idea of MEDUSA is to use the rule based reasoning for the representation of normal cases, the heuristic reasoning for making uncertain, hypothetical inferences on the basis of fuzzy data and fuzzy relations.

The methodologies are listed as follows:

- **Rule-based reasoning:**
  Rule-based reasoning makes use of known and safe knowledge about definite causal associations between symptoms, symptom-combinations and diagnoses, and is appropriate for making certain inferences on the basis of accurate data.
- **Approximate heuristic reasoning:**
  The approximate heuristic reasoning, however, makes use of uncertain knowledge about blurred causal associations in the form of fuzzy relations between symptoms, symptom-combinations and diagnoses and is, therefore, perfectly suited for making uncertain, hypothetical inferences on the basis of fuzzy data and fuzzy relations.

2.2 Internal business logic of the Web-Based Medical Engine: MEDUSA

The Web-based medical expert decision-support system "MEDUSA" is composed of several basic components. The 4 components which marked with bubbles are the most important ones in MEDUSA, and are introduced in the following sections respectively.

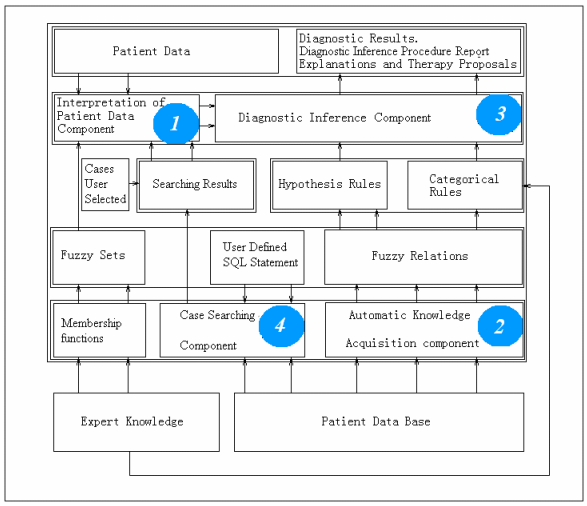

Figure 3: internal business logic of MEDUSA

2.2.1 Interpretation of Patient Data Component

In MEDUSA, a standard patient data questionnaire is used to acquire the symptoms data from the patient with his or her medical history, physical and special examinations. These data are quantities, numeric or qualitative (for instance, the type of pain, and location of pain).

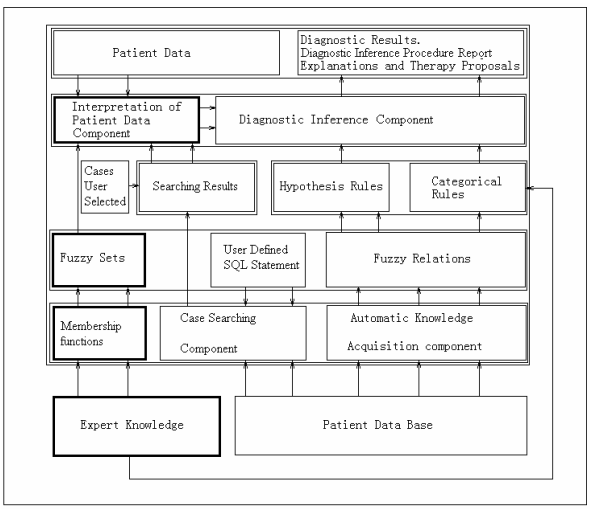

Figure 4: Interpretation of Patient Data Component

Membership functions of the fuzzy sets: The interpretation of patient data component enables the calculation of the degrees of presence for every symptom. The interpretation is based on the representation of the symptoms in form of sharp sets and fuzzy sets. [5] The data are interpreted and thus reach a higher level of abstraction.

Let the membership function of the fuzzy set "elevated temperature", which is defined on the basis of the measured temperatures T, be:

$$m_{S_i} = \begin{cases} 0; & T < 37.5 \\ \left\{ \dfrac{T - 37.5}{0.5} \right\} & 37.5 \le T \le 38 \\ 1; & T > 38 \end{cases}$$

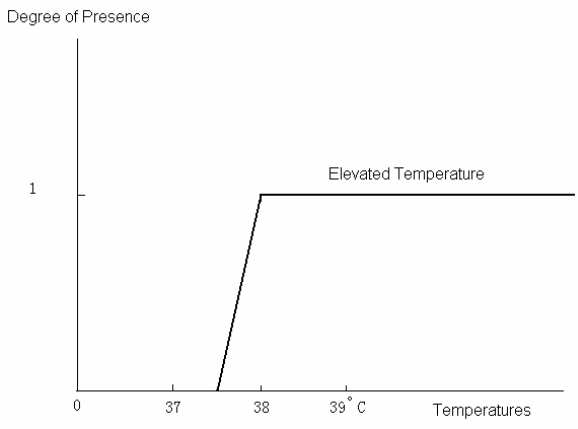

Figure 5: Membership function of Fuzzy Sets

With the given measured temperature of 37.7, the degree of presence of the symptom "elevated temperature" is computed as 0.4.

2.2.2 Automatic Knowledge Acquisition Component

Fuzzy Relations: Different from other fields, diagnosis of AAP is not based on unequivocal categorical, or pathognomonic associations, but mainly on imprecise and uncertain symptom-diagnosis relations. The medical relations between symptoms and diagnoses are represented in the form of fuzzy relations.

Five different types of fuzzy relations:

1) **DS:** how often does a certain symptom occur in connection with a certain diagnosis? (frequency)
2) **DSC:** how often can a certain combination

of symptoms are observed in connection with a certain diagnosis? (frequency)

3) **SD:** to which degree does a certain symptom characterize a certain diagnosis? (selectivity)
4) **SCD:** to which degree does a certain combination of symptoms characterize a certain diagnosis? (selectivity)
5) **SS:** the degree of correlation with the correlating symptoms.

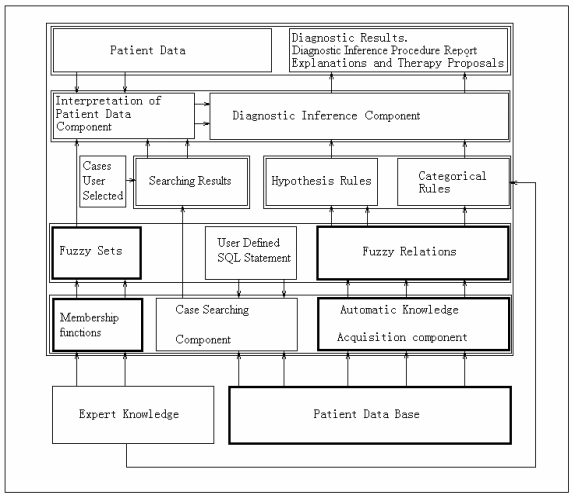

Figure 6: Automatic Knowledge Acquisition component

The automatic knowledge acquisition component enables the automatic acquisition of fuzzy relations between symptoms and diagnoses from a given patient cases database. The SD and DS fuzzy relations are computed by the automatic knowledge acquisition component as follows:

$$D_k S_i = \frac{S_i \cap D_k}{D_k}$$

$$S_i D_k = \frac{S_i \cap D_k}{S_i}$$

S_i : The number of cases showing symptom i

D_k : The number of cases with the diagnosis k

$S_i \cap D_k$: The number of cases with the symptom i and the diagnosis k

2.2.3 Diagnostic Inference Component

The Diagnostic Inference Component is composed of the categorical rule reasoning and approximate heuristic reasoning.

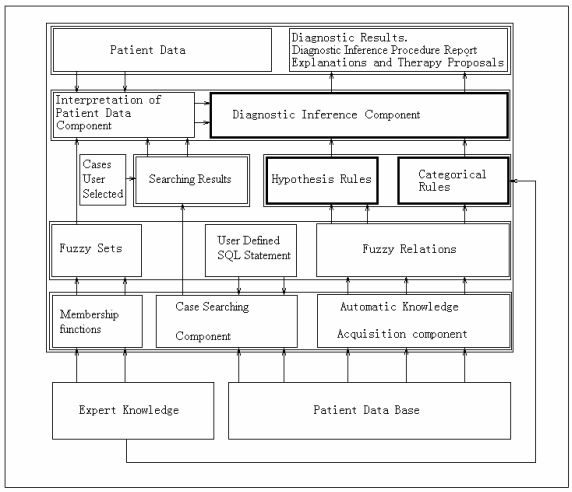

Figure 7: Diagnostic Inference Component

1) Categorical Rule Reasoning:

Category rules are used to store the knowledge about absolutely certain associations. These rules have the following forms:

IF the patient shows S_i (respectively $S_1 \ldots S_n$) THEN the diagnosis is D_k (respectively).

So in this step, all possible certain conclusions are drawn. (For instance, a man will not be a pregnant)

2) Approximate Heuristic Reasoning:

Diagnoses which have neither been excluded or established (hypothesis diagnoses) are evaluated on the basis of the given symptoms and the stored symptom diagnosis relationship. The fuzzy relations and the hypothesis rules are used in this process. For every diagnosis, an evaluation is computed. Dependent on a comparison of these evaluations, the diagnoses are classified as probable, possible or not probable diagnoses.

Hypothetical diagnoses Equations:

Evaluation = the priori evaluation of the diagnosis
+ Evaluation of expected, associated, present or partly present symptoms
- Evaluation of expected, associated, not present symptoms
- Evaluation of present, associated, not expected symptoms

2.2.4 Case Searching Component

For the registered users or medical experts, they can use this component to make composite searching in the patient cases database in the corresponding medical engines.

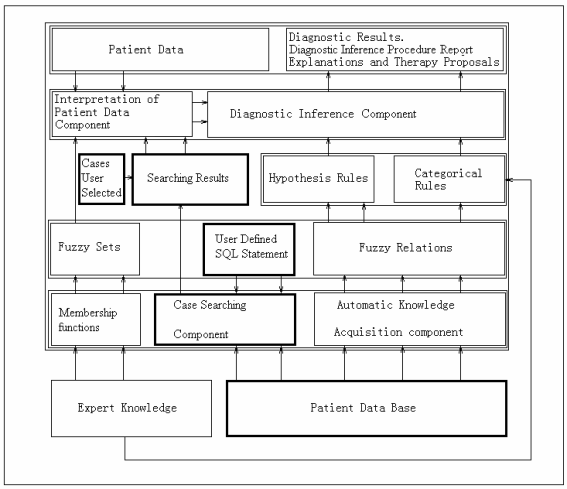

Figure 8: Case Searching Component

In MEDUSA, the Case Searching Component allows the user to customize the table which is used to display the results from the composite searching so that only the symptom columns which the users are interested in will be displayed on the web page instead of displaying cases with all 45 symptom columns.

Every time, the component at most supports the query phrase with the logical relationship between 3 digital symptoms and 5 linguistic symptoms to build the SQL statement to search through the cases database in MEDUSA. After the system feeds back the results, the user can select these cases to view details with their official discharge diagnoses or directly trigger the diagnostic inference component to calculate on. After the calculation, the diagnostic inference results will be displayed on the web-page. Thus, the user has two diagnostic results for one selected patient case, one is the discharge diagnosis from hospital, and the other is the one from our diagnostic inference component of the medical engine. For the registered user, he can click the "View Detail" button to view the report of the entire inference process of the diagnostic inference component which actually provides the possibility for the users to find out the reason why the discharge diagnosis is different or identical with the diagnostic results suggested by our medical engine.

2.3 Functions

The web-based medical engine MEDUSA provides 5 main functions to different roles of uses as showed in Figure 9.

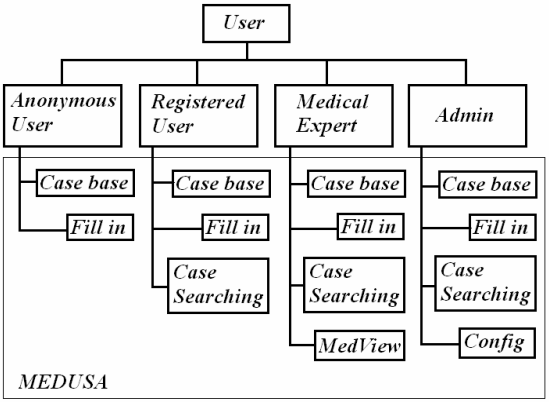

Figure 9: The functions of MEDUSA

1) Cases base: The one designed for the users to make simple searching through the patient cases database. The searching is based on the answers from the 4 simplest questions which are:

1. Your gender?
2. Where is the pain?
3. Which type of the pain?
4. How hard is the pain?

And then all the cases which meet these 4 answers will be displayed on the web page, the user can choose these cases to view details.

2) Fill in: The one designed for the user to make online self-diagnosis.

3) Case searching: The one designed for the registered user to make composite searching through the patient cases database.

4) Med View: The one specially designed for the medial experts to view the internal knowledge attributes and settings of MEDUSA.

5) Config: The one designed only for the administrator to manage, modify and update the medical knowledge attributes or add new patient cases into the patient cases database. The logic flow chart of this function is showed in Figure 10.

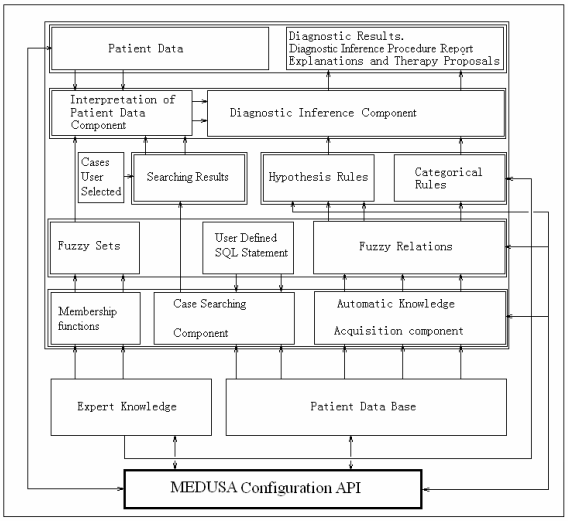

Figure 10: MEDUSA Configuration API

3 The Portal

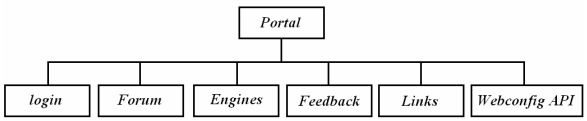

Figure 11: the portal of Online Medical Assistant

The Portal is the interface between the Client and Server. The main functions the portal provides are as follows:

- Prompts the user to type in the data which the web-based system can recognize.
- Acquires users' requests, and delivers them to the Server.
- Presents the responses from the Server to the Client in the web pages.
- Displays the public information of the web-based application.
- Realizes the purview of functions the applications provide to the different roles of users.
- Directs the user to walk through the whole web-based medical applications.
- Provides the platform for the users to communicate with each other.
- Provides the console for the Administrator and other co-operators to work with.

The portal in Online Medical Assistant is actually the coordinator who merges the web-pages, medical engines and APIs into one web-based system.

3.1 The Roles

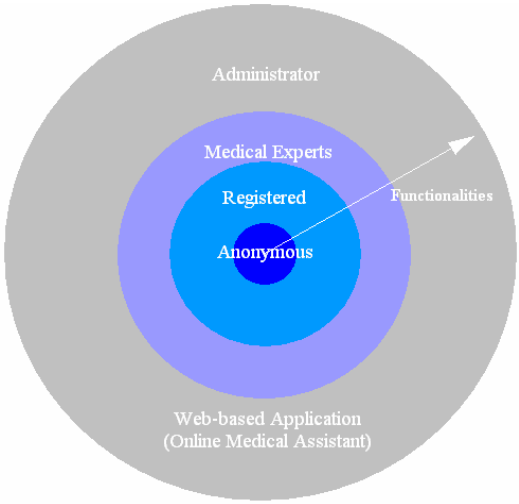

Figure 12: Onion view of roles

There are four types of user roles implemented in Online Medical Assistant, who are:

- **Anonymous Users:** The users who have not registered in the portal.
- **Registered Users:** The users who have registered in the portal.
- **Medical Experts:** The users who have registered in the portal and been assigned the role of Medical Experts by the Administrator. Normally Medical Experts are the persons who are the physicians in the hospital or the medical experts in official medical institutes or research centres.
- **Administrator:** The role of the developer or manager of the system. Administrator is not one person, but a kind of persons who have the right to view the internal medical knowledge settings and attributes of the web-based medical engines, to modify and update the whole website configuration as well. The role of Administrator can be delegated by the default Administrator to medical experts, or registered users.

3.2 Portal Functions

1) Forum: The integration of the Forum into the web-based application is really a big progress in promoting the quality and quantities of the functions the system provides to the users. [7] The Forum in OMA provides the following functions:

1. **Mailbox:**
   With which users can use to communicate with others.
   - **For the medical expert**, it can be used as the private channel to express his or her opinions on certain medical knowledge attributes and settings of medical engines to the administrator.
   - **For the normal registered user**, it can be used to send private messages to the medical experts for consultation or to share personal experiences with other users.

2. **Discussion Sections** which is composed of:
   - **Medical knowledge Section:** The one to be used as the medical diagnoses and symptoms lexicon.
   - **Patient Experience Exchange Section:** The one to be used as the platform to share the users' personal experience in coping with certain specific disease.
   - **Medical Expert Systems Section**: The one to be used as the tutorial for the users to walk through all the functions integrated in Online Medical Assistant.

3. **Search the topics** which the users interest by "post name" or "post author" which proved to be a very efficient way for the users to acquire information they needs instead of finding posts in a dozen of subsections of subsections in the forum.

2) Feedback:
The Feedback is the function the portal provides for the users to rate the OMA and address their personal opinions or suggestions to the administrator. It consists of the following 2 parts:

1. Rate the Web: The user chooses the numbers from 1-9 to rate the quality of the web. The bigger is the better.
2. Give the Reason (Optional): The user can type in his opinion in the text box on the web page and click the "Submit" button to send it to the Administrator.

3) Website configuration Interface:
The link of the website configuration interface will only appear on the web page when the administrator logged in to the website. This is the API specially designed to configure and manage the whole website. With using this configuration interface, we can encrypt all the configuration settings of the website, so that the settings in our web-based applications are in the status of secret, and the security of the whole website is correspondingly promoted.

4 Conclusion

4.1 Summary

During the last decades, computer has been widely used in all kinds of fields. The medical diagnosis can't be excluded either. With the help of computer, the relations between the symptoms and diagnoses are concluded based on not only the experience of physicians but also the statistics of the cases.

The previous traditional medical expert system are the ones which are only computer-based instead of internet-based which tremendously limited the usage of these perfect medical expert systems, and meanwhile the knowledge bases are difficult to be improved as the effort from only a few professionals are obviously not enough. For this reason, the most diagnosis expert systems took many years to develop but still not walk out of the laboratory.

Nowadays, with the big progress in IT technologies, especially the appearance of ASP.NET which is a revolution in the development tools of web-based applications, so that we can locate our medical expert system onto the internet to be a web-based application for the users no matter where they are.

As has been introduced, our Online Medical Assistant is not only a medical expert system for the patient users to make self-diagnosis, but it is a dynamic collaborative web-based system which provides consoles for the medical experts, software engineers, to cooperate with so that the system can be updated directly in the browser without editing thousands lines of source code. Besides, the knowledge base of the web-based medical engines can be expanded with the contribution of the normal registered users and medical experts which makes our system to be a self-learning and self-growing one. Upon these advantages, the accuracy of medical diagnosis is expected to be enhanced remarkably.

4.2 Shortcomings and Outlook

Some Shortcomings of OMA will have to be eliminated in the course of further development and many functions need to be improved and expanded. The most important of these are:

1) The improvement of diagnostic inference reports: The diagnostic inference results should be not as simple as a list of the diagnoses ranked by their corresponding presence possibilities, but also with more additional information, for instance the diagnoses urgency statuses and the corresponding recommendations.

2) Optimize the medical knowledge settings of the medical engine: These medical knowledge settings include the weights and the relationship status between symptoms and diagnoses need to be optimized.

3) The hypothetical diagnoses equations of the web-based MEDUSA should be expanded: The following two sub-equations can be added into the main hypothetical diagnoses equation.

1. Evaluation of associated, present or partly present combination symptoms
2. Correlations between present symptoms

4) More abdominal diagnoses can be added into the web-based MEDUSA: Now the web-based MEDUSA can only give diagnostic inferences on 12 abdominal diagnoses, but the inferences on more diagnoses are expected.

5) More Medical Expert Engines can be added into the system: The Medical Engine MEDUSA is only working on AAP. Later there can be more and more medical engines integrated into OMA which focus on other medical domains.

Acknowledgements

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