FUNCTIONAL DIAGNOSIS FOR MEDICAL PURPOSES BY USING AN INTEGRATED INTELLIGENT SYSTEM

Isoc D[1], Pop M[2], Ignat A[1], Ionescu CM[3], De Keyser RMC[3]

[1] *Department of Control Systems Engineering, Technical University of Cluj Napoca, Romania*
[2] *Department of Phthisisology, 'Iuliu Hatieganu' Medicine and Pharmaceutics, Cluj Napoca, Romania*
[3] *Department of Electrical Energy, Systems and Automation, Ghent University, Belgium*

Abstract: Medical diagnosis using technical means has many applications, especially when the information to be processed is non-homogeneous. Technical means are both instrument or apparatus and software tools. The main outcomes are efficiency and an accurate information processing. This work is dedicated to extent the diagnosis means by integrating together with instrument, apparatus, and software tools, the high qualified knowledge basis existing usually in great university clinics. This integration is achieved so that any member of medical qualified staff working directly with the patient can access a specialized knowledge base using an expert system. This expert system correlates the problem identified by the clinician during the primary investigation and the similar existing cases during a large time horizon inside of the clinic.
The identified problem and the existing knowledge are associated inside of an intelligent predictive algorithm.
The suggested approach is applied in the field of lung diseases where all the necessary features and problems are available.
The outcome of intelligent integrating approach in the chosen application field emphasizes that the results are interesting and economically efficient.

Keywords: medical diagnosis, intelligent system, case-based inference, integrated intelligent system, intelligent prediction.

1. INTRODUCTION

Correct medical diagnosis is a crucial step and condition to ensure an effective monitoring and prophylactic medical attendance. It is more and more necessary to associate medical performance with the economic one: a patient must be treated in optimal way, within the shortest time period and he will be again active in the society after the shortest possible recovering. In the same time, the medical staff must have uniform action level despite his non-homogeneous experience and this action needs to be economically optimal.

The medical diagnosis assumes, simultaneously, both a large amount of knowledge as well as data acquired by technical means (Davis *et al.*,1993; Papik *et al.*, 1998; Kusiak *et al.*, 2000). The overall information processing consists of an assisted support in which medical staff is less (or not at all) involved.

Current outcome in fault detection and isolation (FDI) systems applied in technical environments (Isoc and Ignat, 2004) encourages the monitoring and control of the fault state by means of quantitative and qualitative ways. It encourages the integration of objective information together with other information provided from other sources, inclusively those which refer to human knowledge. On the other hand, the medical diagnosis, by example the diagnosis of lung diseases (Zamora *et. al, 2003.*) is mainly oriented to identify the knowledge.

A special resource in order to build a knowledge-based system is an external and valuable information base. In the case of medical diagnosis, the external resource exists in the frame of university clinics. Despite its great potential, this competence resource wasn't used before.

First part of this contribution introduces the main concepts of the intelligent integrated system and its main running stages. Further the knowledge based system is detailed. An example is approached and finally some concluding remarks are given.

2. SOME DIAGNOSIS CONCEPTS

Similar to any dynamical evolution, the functional diagnosis can be achieved as a consequence of all conditions which are consistent in characterizing the health state of a person as a member (e.g. member of a group with similar diseases).

The functional diagnosis is developed having in mind a normal chaining of states. Each state is characterized by functional parameters and peculiar knowledge. Each state is a consequence of a previous state and a possible premise for a further one.

A patient is represented for the clinician as a typical amount on information acquired by different ways. Part of this information flow is collected by numerous members of medical staff during their activity; and another part is collected by use of specialized apparatus and methods.

There are several possible and necessary ways in collecting information:

- the patient's personal story regards his heredity and past healthy states. This information is represented as pairs of events, called diseases, and time moments. More details are regarding the context of the (medical) events, applied treatments and recovery evolutions.
- the clinician's personal experience and expertise. This information is the most expensive and it is accumulated by experience in large time duration. Currently, this information, this expertise is relative and very rare acknowledged. More than, this expertise disappears with the owner, the clinician.
  Very interesting are the collection of expertise. This kind of collections exists in the frame of university clinics and they are dedicated to instruct the future doctors. The difference between the university collection of expertise and the personal expertise consists in the amounts and quality. The university clinics are establishments where are collected and treated the most difficult and representative cases. In the same establishments, the staff qualification is the highest. That's the reason to consider the university collection of expertise as a reference knowledge source.

  It is worthwhile to remark that in this moment the university collection of expertise is a non-processed one.
- the clinician's current activity in interviewing the patient. The information acquired using this way is always a new one. It is related to the last events occurred in the patient's life. Single this information if very rarely useful. The real value of this information can be established only together with the overall information past ant present regarding the patient. As it was already emphasized the past information regarding the patient is involved in his personal story.
- the medical apparatus collecting data by measuring the patient's functional parameters. This is information is physically speaking an objective information. Nevertheless, there are many situations where this data must be processed or interpreted. The interpretation often assumes also a linguistic conversion. In a preliminary stage, the measured data are first very well concentrated and synthesized, in order to be manipulated by such an intelligent system.

The integration of general information and measured data, together with procedures able to develop information processing like a human being (e.g. expert system), is done in this case by an intelligent system.

3. INTEGRATED INTELLIGENT SYSTEM'S STRUCTURE

As a concrete result of the analysis of functional diagnosis in medical field, a dedicated system was specified in Fig. 1. The *integrated intelligent system* (*IInS*) involves a background expert system having some specialized information basis and subsystems. The knowledge base (*KB*) hosts overall information amount necessary to be inferred in order to obtain alternative decisions as possible diseases for the given patient.

The knowledge base has two main components: expert information supplied by the university clinics and actual information referring to a given patient. The knowledge to be included in KB is collected from the above mentioned sources by a knowledge gathering system (*KGS*). In the same time the information from measurements is collected by a data gathering system (*DGS*). The relation between the patient and the integrated intelligent system is mediated by an *assistive doctor*.
As an application of this intelligent system, the lung diseases were studied; the respiratory function was evaluated and information gathered (Ionescu and De Keyser, 2005).

In a preliminary stage, the system integrated only information from experience - heuristic knowledge. Some further patterns and procedures to transfer specific medical knowledge into effective information are introduced and exemplified. This effective information will be further manipulated by *IInS*. All the system components treating the information after its collection is known as the *expert system*.

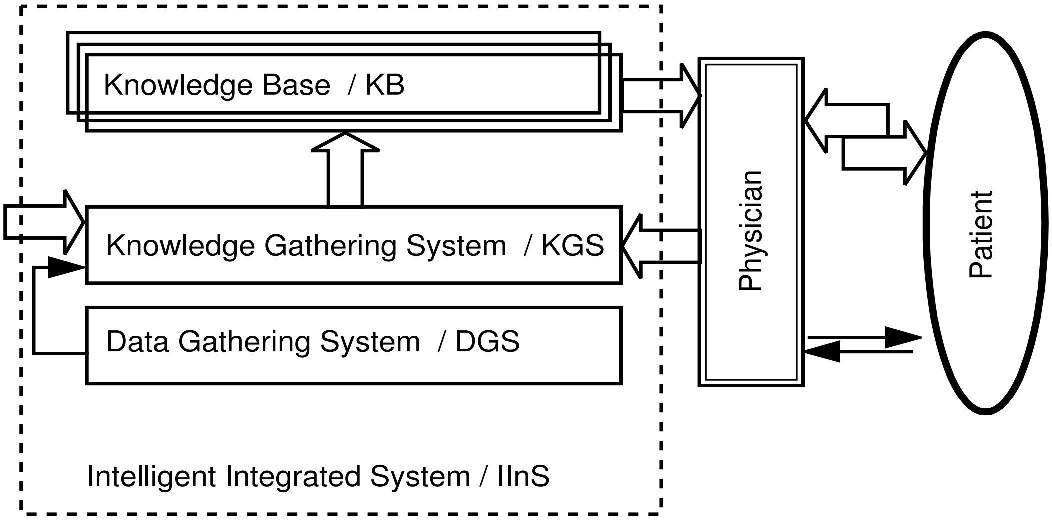

Fig. 1 Structure of the integrated intelligent system (IInS)

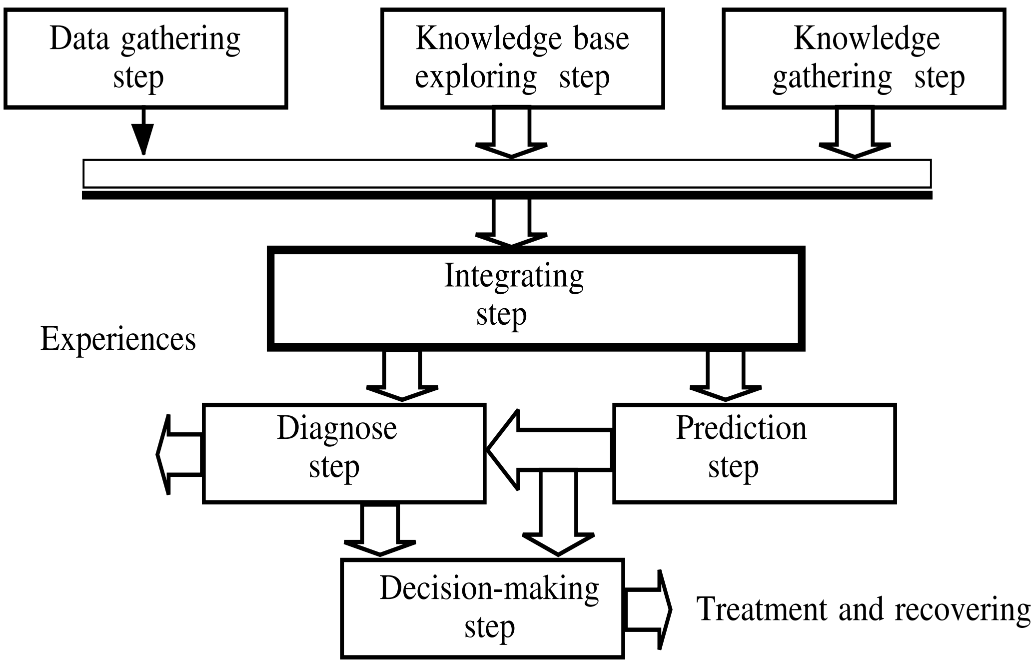

Fig. 2 Necessary steps for an assisted diagnosis process.

4. THE EXPERT SYSTEM'S COMPONENTS

The functionality of this system can be described in some necessary steps as showed in Fig. 2.

The necessary steps for an assisted diagnosis process (ADP) are:

- ***The data gathering step.*** In this step some information are gathered from the human subject using technical means in order to establish the physical, chemical and biological parameters and, as the case stands, to classify them in linguistic values in order to be added in the actual knowledge base of given case or patient;
- ***The knowledge base exploring step.*** This step is acting with a necessary delay because it is fired only when the physician is already informed on the given case (patient). The knowledge base is accumulated during large time duration by high qualified specialists. The involved information is relating to a great amount of cases studied and treated in university clinics.
- ***The knowledge gathering step.*** The information on patients hospitalized in university clinics

are systematically collected in files having an important volume. These files are used as reference sources for medicine school and long life education of members of medical community.

- ***The integrating step*** is a necessary stage in order to build a homogeneous knowledge representation. It is to emphasize that the step integrates information coming from both measured data and knowledge expressed as linguistic wordings more or less 'distillated' in formal logical sentences.
- ***The diagnosis step*** acts as an expert system able to extract the appropriated healthy state face to biological measured parameters and known symptoms defining some illnesses.
- ***Prediction step*** is necessary in order to overcome the lack of experience of young or un-experienced physicians when a patient must to be diagnosed. The prediction is developed in order to find a possible evolution for a given patient, having a given disease, for a given selected treatment.
- ***Decision step.*** This is the final step where the doctor is assisted in establishing an adequate medicine for the subject.

As shown previously, the first step is carried out by the Data Gathering System (*DGS*). The functionality of this system is given in (Isoc and Ignat, 2004; Zamota *et. al.*,2003; Man *et. al.* 2003).

The others three steps are fulfilled by the proposed intelligent (expert) system.

In the next sections some implementation aspects regarding the proposed system are discussed and some solutions are presented.

5. THE KNOWLEDGE BASE SUBSYSTEM

As shown in Fig. 1 an important subsystem is the knowledge base (*KB*).

For a human subject, like in any dynamical evolution, the functional diagnosis can be predicted as a consequence of all conditions which are consistent in characterizing the health state of a person as a member (e.g. member of a group with similar diseases). The problem is how to be able to establish this diagnosis and how to predict the further evolution for a human subject? All the answers can be found in the knowledge stored by an expert, in this case a specialist doctor.

Another way to tackle this problem is to build proper and use properly a knowledge base system consisting on some gathered and registered data from human subjects.

The necessary data for such a knowledge based system rests in facts and heuristics.

The facts are some available data which can be gathered, in this case, from the human subjects and which are generally accepted by all the experts. For the proposed expert system these data consist from some measured signals, namely the breath flow and pressure and some exogenous information regarding for example the subject's age, some previous diseases of him or of his direct relatives, his living region, etc.

In a preliminary stage, the measured data are first very well concentrated and synthesized, in order to be mani\-pulated by such an intelligent system. In this preliminary stage a knowledge base is build in a manner which will permit in next stages, by using an adequate inference mechanism, predictions, diagnosis and decisions for a human subject.

Also, the knowledge base subsystem has to allow in later stages the possibility to add new knowledge gathered from the gathering subsystem.

6. THE KNOWLEDGE GATHERING SYSTEM (*KGS*)

For an expert system, based on gathered knowledge, the performance depends directly on the size of the used know\-ledge base and their intrinsic quality and trueness. For such reasons, in order to build the knowledge base, large biomedical tests are necessary to be made. But these tests have to be made very carefully, because the subjects have to be choosing in a way which permits to represent the desired target population and diseases. Also, if many measured experiments are carried out on the same subjects, some extra protection measures have to be taken, because there is a real risk to dilate unavailing the size of the data base.

All the biomedical testing devices are based on the some typically elements (Wayman, 200):

- ***Cooperative and non-cooperative.*** These two properties will do the trick especially in the first stage of gathering data for the data base.
- ***Overt and covert.*** These two testing elements are linked with the previous two. If the human subject is noticed about the experiment he can try to dissimulate the results and the diagnosis, prediction and decisions decision steps can be altered.
- ***Habituated and non-habituated.*** If the human subject is not acquainted with the system and the signal assay techniques, some errors can appear in the gather step. For this reason the biomedical system has to be attended.
- ***Attended and non-attended.*** For this stage the biomedical system has to be attended by some user.
- ***Public and private.*** The human subjects have to be choosing carefully for a good build the knowledge base. In order to achieve this goal it's advised

to use a private investigation evolve on human subjects from clinics or hospitals.

- ***Open and Closed.*** In a globalization area the exchange of data between different biomedical systems is a wonted issue, but in this stage it's sufficient to provide a way to exchange data only between different biomedical systems of the same kind.

7. AN EXAMPLE AND A POSSIBLE OUTCOME

Supose a lung disease *D* having as main symptoms $S_{m1}, S_{m2}, \ldots, S_{mm}$.These symptoms can be identified using both the interviewing of patient and measuring their biological parameters. After the first contact with the patient, the clinician finds a larger set of symptoms as $S_1, S_2, \ldots, S_{m'}$ where $m' \geq m$.

In order to decide on a realistic disease, the clinician has to do some actions:

- To reduce the number of found symptoms m' to m eliminating false symptoms for the existing disease. The elimi-nating of false or additional symptoms is temporary a necessity in order to identify the main disease. These additional symptoms will be later used because it is possible that the patient has a complexity of diseases. Among these only one is of the considered class. Other symptoms are detected but in this stage they haven't yet a well identified disease. This situation is possible to hide a set of complications of the main identified disease.
- To select an optimal treatment having as target to cure the patient. This treatment must be applied and the recovering must be the shortest possible.

The patient has a personal story P where there are included both the patient's heredity and the past diseases, D_i together with their recovering R_i. Of course for each person the diseases appeared at different time moments and the recovering has different durations.

To find the appropriate solution (diagnosis, treatment) for the given problem (patient, disease) the clinician must integrate past information about both the patient and other patients found at least once in similar situations and the last information regarding the newest situation.

Previously, in university clinics there existed subjects in similar situations patients like described in Table 1.

In Table 1, each patient, P_i, has a personal story St_i. The medical evolution is described during a set of years so that t is the present time moment and $(t-11)$ is the elf-th year before.

The selected patients, were, each at a given time moment, hospitalized in the clinics having the studied disease with its typical symptoms $Sy_1 \ldots, Sy_m$, and sometimes, other associated symptoms $Sy_{m+1}, Sy_{m'}$. The doctors of university clinics have recommended in each situation a treatment, Tr_i and the associated recovering time Rt_i, with the values of $T_1, T_2, \ldots$ has occurred. Of course each recovering time is typical to a patient.

The supervising time period when a patient is monitored is overlapped on the life of each patient. The patient's life and heredity are reasons for his typical behavior before the disease and treatment.

The overall information about patients is available, more or less precise and detailed, inside their files existing in clinics.

This information is collected and organized in the knowledge base in manner similar as in Table 1.

When a new patient is examined, the clinician collects the information describing his healthy state both by interviewing him and measuring his biological parameters.

The expert system of integrating intelligent system put together the information and is searching the most similar sequences of life, heredity and evolution of disease in the university clinics knowledge base.

The information found is used as a known experience in order to develop an inference procedure having as outcome a particular treatment for the examined patient. The inference procedure will offer the most often a set, smaller or larger, of recommended treatments. For each treatment the expert system gives the possible recovering time and some information about possible evolution of healthy state.

Table 1. Patients and stories.

Patient	P_1,St_1	P_2,St_2	P_3,St_3	P_4,St_4	P_5,St_5
t	-	-	-	-	-
t-1	-	-	-	-	-
t-2	-	Sy_{m+3}	-	-	Sy_{m+2}
t-3	$Sy_1 \ldots Sy_m$,	-	$Sy_1 \ldots Sy_m$,	-	Sy_1, Sy_{m+2}

	Sy_{m+1},Sy_{m+5}, Tr_1,Rt_1=T_{1-}		Sy_{m+2},, Tr_3,Rt_3=T_3		
-t-4	-	-	-	Sy_1, Sy_{m+2}	Sy_1…Sy_m, Sy_{m+2},, Tr_3,Rt_3=T_3
t-5	-	-	-	-	-
t-6	-	-	-	-	-
t-7	-	-	-	-	-
t-8	-	Sy_1…Sy_m, Sy_{m+2},, Tr_2,Rt_2=T_2	-	-	-
t-9	-	-	-	Sy_1…Sy_m, Sy_{m+2},, Tr_3,Rt_3=T_3	-
t-10	--	-	-	-	Sy_3, Sy_{m+4}
t-11		Sy_{m+1}	-	-	-
…..	-	-	-	-	-

8. CONCLUDING REMARKS

The suggested *IInS* structure proved to be appropriate and allows processing specific information, assisting the medical staff, and at the same time updating the above information with measured data collected by the staff by means of medical apparatus and methods.

The necessity of integrated systems appears due the non-homogeneity of information available during the disease detecting, identifying and curing.

The intelligent system is associating the information collected in real-time during the patient's examination with the information acquired long time ago regarding similar patients having similar symptoms and personal stories.

The inference process developed inside of intelligent systems allows other criteria than medical to be added during the decision-making. Among these criteria, the most interesting are the economical and the social one.

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