Medical Informatics: A look at Computer-Aided Diagnosis

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ABSTRACT

As the work of the physician become more demanding, challenging and complicated, the need for computer programs to aid and ease the problem has become inevitable. New generation of programs designed to emulate clinical expertise and different types of decision support methods are used in medicine today. These so called "expert systems" can be used in for example interpretation of medical images, medical diagnostics etc. Diagnostic systems are developed based on different mathematical and reasoning concepts. Most of these concepts apply rules, logic, probabilities and heuristics reasoning processes to an integrated knowledge base to make diagnosis. It is very useful that a computer aided diagnosis follow a structure and standard that can aid it to model the art of real medical diagnosis. Diagnostic systems are an invaluable tool for researchers, health professionals and the academia. These systems have strengths and weaknesses and require constant checks and evaluation. Their analytical and mathematic strengths surpass that of the physician whiles their weakness, as far as scope of operations is concerned, leaves more room for research. The user (preferably a physician) of a diagnostic system should have thorough knowledge about its domain of competence. In developing such a system it is essential that the developer work hand in hand with a medical expert and information input should be considered vital essential for the viability of the system. Computer aided diagnostic systems cannot independently perform diagnostic consultations. However they are useful companions to health professionals therefore more work should be down to integrate them into the general work flow of health care.
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1 INTRODUCTION

A computer aided diagnostic system is a computer program that can be used to carry out an appropriate medical diagnosis. There is an increasing pressure at the hospitals due to population increase. Hence the task of doctors and clinicians are becoming harder day by day. But in the advent of information technology, this unavoidable work can be reduced. Over the last 20 years, computer-based systems designed to support clinical decision making have evolved from prototypes (MYCIN, INTERNIST-I) to commercially available systems (ILIAD, GIDEON, TRAUMAid, Isabel etc.). Obviously many of these systems address narrow areas of subject matter, but on the other hand systems intended to address the entire field of internal medicine is gained increasing visibility (though still bleak). Although most of these systems are generally designed to provide efficient access to medical information, they also include mechanisms for the assessment of clinical and laboratory data and the provision of diagnostic advice. As such systems become more widespread, evaluation of their diagnostic accuracy and usefulness to physicians is necessary. This paper looks into computer-aided diagnosis (CAD) in medicine, the background and concepts employed by these expert systems, the task of medical decision making as well as some case studies. It further discusses their strengths and weaknesses and concludes with some recommendations.

2 BACKGROUND AND CONCEPTS

Most research work on CAD began in the 1960s when researchers tried to use mathematical formula to represent difficult clinical problems (Schwartz, 1987). The application of Boolean algebra, pattern matching, decision analysis et cetera to resolve diagnosis process was the order of the day. Unfortunately (except in extremely narrow clinical domains) these techniques had little or no practical value at all. The conclusion came by many researchers was that for a mathematical model or program to work it must mimic the behaviour of a clinical expert. In the 1970s attention then shifted on the study of the actual problem solving techniques of clinical experts. The resulting insights have subsequently been used to construct models of clinical problem solving that, in turn, have been converted into expert systems like CAD.

2.1 Pioneering Concepts

Ledley and Lusted (1959) observed and outlined some reasoning concepts which where
an essential component of medical reasoning. Two of these concepts; logic (which is based on set theory and Boolean algebra) and probabilistic (which is embodied in Bayes’ rule) were the much talked about and they formed the underlying principles behind the development of CAD systems over subsequent decades.

Logical systems, which are mostly dependent on discriminating questions to distinguish among mutually exclusive alternatives were better used in narrow domains, especially in those cases where it was certain that only one disorder might be present (Bleich et al (1969). Problems arise in cases where the system uses branching logic. Medical decision making is not “black and white” and may contain many shades of grey issues. For example a patient may experience a symptom for a variety of interrelated reasons, and hence searching for single answer in such a case might be futile.

Most commentators feared that using conditional probability (Bayes’ rule) for diagnostic problem solving was only of theoretical interest. Warner and his colleagues in 1972 developed one of the first medical application systems based on Bayes’ rule. They reiterated how important it was to obtain accurate data for the system’s knowledge base since a conditional probability based on false premise leads to incorrect answers. They were the first to propose a “gold standard” to judge the performance of CAD systems. A wave of enthusiasm surrounds current work on Bayesian belief networks for medical diagnosis.

One of the much talked about early expert CAD system is MYCIN, which was developed in the 1970s by Shortliffe and colleagues at Stanford University. This program uses rules to diagnosis bacterial infection and subsequently recommends a therapy. A large number of rule-based diagnostic systems have been developed over the years, but most of them have been devoted to narrow application areas, due to the extreme complexity of maintaining rule-based systems with more than a few thousand rules. An example of a recently developed rule-based system in a focused domain is TRAUMAID (developed by Clarke and Webber); which is used for diagnosis and treatment of penetrating injuries to the chest or abdomen.

A preferred alternative to logic and probabilistic reasoning concepts is heuristics. Anthony Gorry was an enlightened pioneer in the development of heuristic diagnostic systems that employ symbolic reasoning. His approach to the medical diagnosis problem with expert-systems was based on the use of a generic inference function, which is used to generate diagnoses from observed findings and a test-selection function that
dynamically selects the best. He also proposed thorough tests on competing diagnoses (and inherent issue with heuristic systems) since in such cases there is a high chance of ignoring the right diagnosis during the selection. Gorry’s outstanding contributions represent the intellectual ancestors of a diverse group of medical diagnostic systems including the PIP (Present Illness Program), MEDITEL, INTERNIST-I, QMR, DXplain and ILIAD, just to mention a few.

2.2 Current Trends

Evolutions of diagnostic systems during the 1980s and 1990s have been motivated by changes in hardware platforms and user interfaces; by philosophical changes in the perceived role of diagnostic decision systems; by new models for diagnostic decision support; and through expanded understanding of how to evaluate diagnostic systems.

The proliferation of the microcomputer and the advent of networks made it possible for system developers to distribute diagnostic systems in a cost-effective manner to a large user community. The microcomputer platform also encouraged development of user friendly sophisticated graphic user interfaces for CAD systems. Better evaluations from a broad-based audience allowed developers to evolve systems and also follow standards akin to clinical practise.

There is also now a change in perception about the use of CAD systems. The previous thought of a CAD system as a “Greek oracle” is long forgotten. The original INTERNIST-I program treated the physician as unable to solve a diagnostic problem (Miller, 1994) and the omniscient consultative program was just supposed to provide the diagnosis. The physician’s role was just a passive observer answering yes or no to questions generated from the system.

For some time now there was a strong resistance in the medical society on CAD systems. Clinical professional have been dragging their feet to entering data into a computer. Physicians have been conservative, exhibited fears that their work was being threatened by a prospect of being replaced by the machine. Some were also of the opinion that these systems have been founded on unrealistic models. Education and the need to change with technology have aided CAD systems to gain more recognition and acceptance. Today they are a companion to the physician, researchers, medical students and relevant players in medical circles.
3 THE TASK OF MEDICAL DIAGNOSIS

In reality medical diagnosis is a contingent and emergent process (Armoni 2002) which has no defined structure or protocols. This makes modelling of programs to emulate a physician in diagnosis a difficult and complicated issue. A computer-aided diagnostic system is deemed useless if it cannot in some way model the task of medical diagnosis.

3.1 Modelling Differential Diagnosis with CAD Systems

Designers of CAD systems have coined the physician’s decision making task as one of ‘differential diagnoses’ (Pople, 1982). Differential diagnosis is an analytical undertaking where the physician is faced with a set of diagnostic alternatives where his primary aim is to ascertain whether he has at hand enough information to make a diagnosis and if not determine whether to investigate more for additional information.

Many different algorithms and techniques have been proposed to structure or standardise differential diagnosis. It would have been easier if it could be formulated into lay-down rules or protocols but as said earlier this is very complex. One reason is that the physician might not formulate and appropriate differential diagnosis as he might be faced with a case of rare disease, two or more diseases working together and other complications that might generate abnormal findings which could be interpreted in various ways. Another issue worthy of note is discrepancies that might crop up due to misrepresentation by the patient or their family, wrong laboratory results and tests. These complexities can also be attributed to incomplete information on the disease(s) in question by the physician or medical society.

For a model to be successful it is required that the physician knows a priori which is the correct differential diagnosis to the problem at hand. It is not shocking that even highly skilled clinicians sometimes require assistance to formulate alternatives during a diagnosis process. It is against this backdrop that extra care has been taking in drawing out procedures and algorithms to modelling differential diagnosis into successful CAD systems.

It is interesting to note that there is an aspect of differential diagnosis which could not be captured by models. This aspect is the creative part of medical reasoning by the physician which many see as an “art” rather than mathematical formulas.
3.2 The "Art" of Diagnostic Reasoning

Clinical professionals have argued that the process of clinical decision making is an art rather than science. They are of the view that computer programs can never emulate the art of medical diagnosis as this is borne out of experience and skill acquired through consistent practice. They maintain that a computer program can only deal with the analytic and scientific aspect of their work.

Various techniques have been used to examine that which differentiates the expertise of a skilled clinician. It has been realised that the physician react to signs in the clinical data by placing one or more diagnostic tasks into concepts which then play an important role in subsequent decision making process. The range of alternatives to be considered in the diagnostic decision process and the obtaining of more information is directed by this conceptualisation. With experience an accomplished physician can use hints in the patients’ medical records to formulate a befitting differential diagnostic tasks.

This lack of creativity by CAD systems contributed to the reluctance of their usage in the medical community. Many have questioned their efficacy even though reports have shown that these programs might perform better than non-specialist in their respective domains (de Dombal et al, 1973).

3.3 Strategizing Diagnostic Decision Making

Decision making is all about strategies and diagnostic decision making is no exception. During medical diagnosis the physician is most often than not face with a daunting task of eliminating perceived candidates form various possibilities. When faced with alternatives to choose from, what reasoning process will he use to narrow the possibilities to the correct one? On selecting and elimination if his premises are wrong the final decision is also wrong and this will lead to misdiagnosis and the consequences are obvious. This aspect of diagnosis requires resolute strategies that will enable the physician to carry out a meaningful diagnosis.

One of the significance of a physician's conceptualisation of a diagnostic problem is the role it can play in strategising the decision process. The physician can have an idea of what sort of relevant information to acquire for the diagnosis. As to what kinds of
questions to ask the patient, what kind of laboratory tests are necessary, which area needs further probing and which other specialist need to be consulted et cetera, all become clear to the physician?

Once the right questions have been asked and the right data acquired, the diagnostic decision becomes quite trivial and clear. Formulating plausible strategies that will result in successful diagnosis is a challenging task which differentiates an expert. Computer aided diagnostic systems will only be successful when they are based on lay down and tested strategies in clinical decision making.

### 3.4 The Structuring of Medical Diagnostics

There has been wide spread criticism of the ill structuring of diagnostic programs. Harry Pople proposed and outlined approaches to computer aided diagnosis. He categorised them as:

- The nature of the problem.
- The procedure employed to solve the problem.
- Allocating responsibilities to the physician and computer program in diverse aspects of the procedure.

Since CAD systems are used for various areas of medicine a need for standards based on well organised structures for these various categories is very essential. Pople implied that most diagnostic programs falls into a category which he term “degenerate category”. He based this on the fact that most programs yield successful outcomes by following procedures. Thus CAD systems upon given a set of diagnostic possibilities requires a particular procedure during the differential diagnosis. This can further predict the method and strategy to employ. An example of a strategy employing Bayes’ rule is when the set of diagnostic possibilities are for example exhaustive and mutually exclusive.

Another approach to the structuring of medical decisions process that might yields differential diagnostic task is the method most commentators in the field refer to as "noticing and evoking". By noticing the problem at hand and the list of diagnostic possibilities the program will subsequently evoke a particular diagnostic procedure that is germane to the problem in question.

It might be useful to structure differential diagnostic procedures around certain combinations of findings (Patrick et al, 1983), which, when they occur together in a
patient, may be presumed to be part of the same underlying process. They suggested use of "activation rules" that would be used to evoke particular differential diagnostic tasks based on the outline of results. Critics of this approach have argued that when algorithms are designed to be invoked on the basis of patterns of findings (laboratory or clinical) there is bound to be many potential inaccessible diagnosis; especially those that cannot be accounted for in the evoking pattern. There is therefore the danger that reasonable explanations of the diagnostic problem might not be given comprehensive consideration.

It should be noted that structuring of medical diagnosis can take many divergent forms of opinion. But at the end of the day the important issue is a structure that will yield pertinent results.

4 CASE STUDIES

We have come a long way in looking at the background, significant concept and the task of medical diagnostics. In this chapter three computer aided diagnostic programs will be explained. INTERNIST-I and MYCIN were part of the earlier systems developed. Even though they were prototypes many modern diagnostic programs were built based on their underlying principles. GIDEON is talked about because it one of those still in use today.

4.1 MYCIN

This program is one of the first talked about expert system in medicine. It was developed in the 1970s by Shortlife and colleagues at Stanford University to aid as a consultant to help identify infectious diseases (and organisms causing them) and chooses a relevant therapy; usually selecting an appropriate drug (Randall, 1982). MYCIN is a typical rule based system. A rule based concept was chosen as an alternative due to problems, limitations and complexity associated with other approaches.

4.1.1 Objectives for design

The developers of MYCIN had some design goals in mind. These were:

- High performance and consistency – this was necessary for the program to be dynamic and flexible enough to cater for constantly changing technical knowledge in the field and subsequent update of the programs “knowledge base”.
- An ability to handle an interactive dialogue – that is the program should be able to
justify its decisions and results.

- Certainty of results – program should be able to measure how certain it is of its result due to possible incompleteness and inexactness that may arise because of combination of rules and data.

### 4.1.2 System design and modus operandi

Fig 1 and Fig 2 show extract of a sample dialogue with MYCIN. User type-in is in boldface capitals and italicized comments are not part of actual dialogue.

```
--------INFECTION-1--------
5)  What is the infection?
** PRIMARY--BACTEREMIA
6)  Please give the date and approximate time when signs or symptoms of the primary-bacteremia (INFECTION-1) first appeared. (mo/da/yr)
** MAY 5, 1975
The most recent positive culture associated with the primary-bacteremia (INFECTION-1) will be referred to as:
--------CULTURE-1--------
7)  From what site was the specimen for CULTURE-1 taken?
** BLODD
   = BLOOD
8)  Please give the date and time when this blood culture (CULTURE-1) was obtained. (mo/da/yr)
** MAY 9, 1975
The first significant organism from this blood culture (CULTURE-1) will be referred to as:
--------ORGANISM-1--------
9)  Enter the identity of ORGANISM-1:
** UNKNOWN
   {typically the identity is not known and must be inferred}
10) Is ORGANISM-1 a rod or coccus (etc.)?
** ROD
11) The gram stain of ORGANISM-1:
** GRAMNEG
12) Did ORGANISM-1 grow aerobically?
** YES (.8)
13) Is the patient's illness with ORGANISM-1 a hospital-acquired infection?
** ?
   Was the infection with ORGANISM-1 acquired while the patient was hospitalized?
   Expected responses are: YES NO
   Enter HELP for list of user options.
** Y
   {more questions follow, to gather sufficient information to infer possible identities of the infecting organisms}
```

**Fig 1. Initial part of a consultation.**
My therapy recommendation will be based on the following probable infection(s) and potential causative organism(s):

INFECTION-1 is PRIMARY-BACTEREMIA {possible identities}

Item 1) The identity of ORGANISM-1 may be PSEUDOMONAS-AERUGINOSA
Item 2) The identity of ORGANISM-1 may be KLEBSIELLA-PNEUMONIAE
Item 3) The identity of ORGANISM-1 may be E.COLI
Item 4) The identity of ORGANISM-1 may be BACTEROIDES-FRAGILIS
Item 5) The identity of ORGANISM-1 may be ENTEROBACTER
Item B) The identity of ORGANISM-1 may be PROTEUS-NON-MIRABILIS

On a scale of 0 to 4, where higher numbers indicate increasing severity how would you rate Fred Smith's degree of sickness?

** 3

47) Does Fred Smith have a clinically significant allergic reaction to any antimicrobial agent?

** NO

48) Fred Smith's weight in kilograms (or <number> POUNDS):

** 70

(note that 2 drugs cover for 6 potential organisms)

[Rec 1] My preferred therapy recommendation is as follows:

In order to cover for Items <1 2 3 5 6>:

Give: GENTAMICIN
Dose: 119 mg (1.7 mg/kg) q8h IV [or IM] for 10 days
Comments: Modify dose in renal failure

In order to cover for Item <4>:

Give: CLINDAMYCIN
Dose: 595 mg (8.5 mg/kg) q6h IV [or IM] for 14 days
Comments: If diarrhea or other GI symptoms develop, patient should be evaluated for possible pseudomembranous colitis.

Do you wish to see the next choice therapy?

** Y {alternative choices are available}

Which, If any, of the above drugs do you wish eliminated from consideration?

** CLINDAMYCIN

[Rec 2] Next best therapy recommendation:

In order to cover for Items <2 3 4 5 6>:

Give: CHLORAMPHENICOL
Dose: 1 gm (15 mg/kg) q6h IV for 14 days
Comments: Monitor patient's white count

In order to cover for Item <1>:

Give: GENTAMICIN
Dose: 119 mg (1.7 mg/kg) q8h IV [or IM] for 10 days
Comments: Modify dose in renal failure

Fig. 2. Final segment of a consultation.

The knowledge base of MYCIN is an integration of a set of decision rules. Fig 3 below shows and example. The program uses these rules to draw conclusions. It also associates its results with a certainty factor to deal with the problem of incompleteness and
inexactness. The certainty factor is in the range of 0-1 with 1 being the highest.

If 1) the gram stain of the organism is gram negative, and
   2) the morphology of the organism is rod and
   3) the aerobicity of the organism is anaerobic,
Then there is suggestive evidence (.7) that
The identity of the organism is Bacteroides.

Fig. 3. Typical medical decision rule.

Another interesting feature of MYCIN is its ability to justify its conclusions. An example can be seen from Fig 4.

(i) ** HOW DID YOU DECIDE THAT ORGANISM-1 MIGHT BE AN E.COLI? 
   I used RULEO21 to conclude that the identity of ORGANISM-1 is e.coli. This gave a cumulative CF of (.47).
   Then I used RULE084 to conclude that the identity of ORGANISM-1 is e.coli. This gave a cumulative CF of (.55).
   Finally, I used RULE003 to conclude that the identity of ORGANISM-1 is e.coli. This gave a cumulative CF of (.74).

(ii) ** WHY DIDN'T YOU CONSIDER STREPTOCOCCUS AS A POSSIBILITY FOR ORGANISM-1? 
   The following rule could have been used to determine that the identity of ORGANISM-1 was streptococcus: RULE033
   But clause 2 ("the morphology of the organism is coccus") was already known to be false for ORGANISM-1, so the rule was never tried.

Fig 4. MYCIN’s ability to justify its conclusions.

4.2 INTERNIST-I

This system was developed in the early 1980s at Pittsburgh University (Miller et al, 1992). The program uses heuristic procedures that compose differential diagnosis on the basis of medical evidence to make complex and even multiple diagnoses. This is accomplished by accumulating sets of disease entities and observed disease manifestations (signs, symptoms, lab information etc) which are exhaustive and mutually exclusive. This forms the basis for strategizing the differential diagnosis for the clinical problem at hand. There has been some remarkable success when the program was used to examine some difficult clinical problems (Pople, 1982).
4.2.1 **System features**

The INTERNIST program has two fundamental type incorporated into its knowledge base. These are notably disease entities and disease manifestations. There are several hundreds of disease entities and manifestation together with their relations encoded into the knowledge base.

Each manifestation is associated with a list of diseases which the said manifestation is clinically known to appear. A weighting factor (0-5) is also included to ascertain the strength of the association.

Conversely each disease entity in the knowledge base also contains a list of manifestations which is clinically known to occur in the said disease. Here a frequency weight (on a 1-5 scale) is used to establish the frequency of occurrence.

The relation between disease entities and their associated pathological states are also defined. These also have relevant weighting factors and frequency weights.

The knowledge base of INTERNIST-I also contains a classification of diseases which is structured in the order of organ systems. An example is “heart disease”, “kidney disease” et cetera. This classification is hierarchical and can even contain subdivision which also can be divided until the individual disease entity is attained.

4.2.2 **Modus Operandi-INTERNIST**

During a typical diagnostic consultation with INTERNIST-I its heuristic problem structuring process is repeatedly invoked to systematically solve the problem at hand.

In such a process, firstly, the patient’s data (both positive and negative findings) are entered into the system without paying attention to the amount and order. The positive findings trigger the fundamental differential diagnosis task and each of them is considered.

A scoring system is use by the program to award points to disease hypothesis on the basis of their weighting factor and importance of their associated manifestations. A ranked list of disease hypothesis is created and heuristic criteria are used to select highly ranking
ones which will subsequently form the composition of the differential diagnostic task. In the next stage the program uses questions to eliminate some of the alternatives in the decision domain. Cases of high alternatives (usually five or more) are ruled out and others are discriminated by using the negative findings to disconfirm them. The alternatives in the domain are narrowed to one and the program employs confirmatory data to pursue the likely contenders.

Finally, the program acquires more data (both positive and negative patient data) and re-examine all the diseases evoked and then reformulates the differential diagnosis. The disease entity which emerges as most highly rated on successive iterations is selected and entered into a list of concluded diagnosis. See Fig 5 for extract of sample program.

Please Enter Findings of INSPECTION AND PALPATION EXTREMITY <IES>
*GO
LEG <S> EDEMA BILATERAL ?
NO
ABDOMEN TENDERNESS GENERALIZED ?
NO
ABDOMEN TENDERNESS RIGHT UPPER QUADRANT ?
NO
DISREGARDING: SKIN SPIDER ANGIOMATA, CREATININE BLOOD INCREASED,
UREA NITROGEN BLOOD 60 TO 100
CONSIDERING: ONSET ABRUPT, FECES LIGHT COLORED, JAUNDICE, LIVER
ENLARGED SLIGHT
DISCRIMINATE: HEPATIC LEPTOSPIROSIS, LARGE DUCT OBSTRUCTION

The abrupt onset of the illness tends to eliminate the chronic liver diseases from serious contention. However, the program does not yet have access to the results of liver function tests, which would help to discriminate between hepatocellular and cholestatic forms of acute involvement.

Please Enter Findings of TRANSAMINASE <S>
*SGOT GTR THAN 400
*SGPT 200 TO 600
*GO
DISREGARDING: SKIN SPIDER ANGIOMATA, CREATININE BLOOD INCREASED,
UREA NITROGEN BLOOD 60 TO 100
CONSIDERING: FECES LIGHT COLORED, JAUNDICE, LIVER ENLARGED
SLIGHT, SGOT GTR THAN 400, SGPT 200 TO 600
NARROW: HEPATIC LEPTOSPIROSIS, HEPATITIS ACUTE VIRAL

The term NARROW signifies that the task formulation procedure has constructed a broad differential list that would ordinarily suggest use of the RULEOUT strategy; however, as there are no helpful questions available without resorting to laboratory procedures, the field is arbitrarily restricted to the two leading contenders, and the DISCRIMINATE strategy is employed.

Fig 5. Extract of INTERNIST-I sample program
4.3 GIDEON

Global Infectious Diseases and Epidemiology Network (GIDEON) is an expert system that employs Bayesian matrix for the diagnosis of infection diseases in different parts of the world. GIDEON, which is still used by a wide range of personnel in the medical field, was developed about a decade ago by a group of Israeli, American and Canadian scientist. The program consists of four seamlessly chained component modules.

The first “Diagnosis” generates a Bayesian ranked differential diagnosis based on manifestations (signs, symptoms, laboratory tests, country of origin, and incubation period) to diagnose and simulate infectious diseases in various countries.

The second “Epidemiology” draws attention on the epidemiology of every possible outcome of the differential diagnosis.

The third “Therapy” recommends appropriate antibiotics, antiviral, or even vaccines for the microorganisms causing the infection.

Lastly “Microbiology” is for updating the knowledge base and for information retrieval.

4.3.1 Design Features

The design consists of interactive database representing rates and clinical probabilities constructed for hundreds of diseases, symptoms, signs and laboratory findings in several countries. The database is updated periodically from trusted sources such as technical reports statistics published by the World Health Organization, reports from various national health ministries and evident data from journals and periodicals. The database is limited to only infectious diseases and also clinical evidence and epidemiological information is fed into it continually.

GIDEON is a user friendly interactive graphical user interface program. This enables a very easy use of the program and the user can even ask the program to justify its results.

4.3.2 Modus Operandi-GIDEON

The program user is first requested to indicate (Fig 6) the signs and symptoms of the
Fig 6 Initial user input interface

Fig 7 Differential diagnosis after input
afflictions, the country of disease origin, date it begun and how long. As seen from Fig 7 above the user input is processed by a Bayesian matrix and a ranked differential diagnoses is presented in order of probability in a bar graph and numerical format.

In the next phase the user is interfaced with enormous epidemiologic information including countries endemic for the diseases, their global status and information on their signs and symptoms. The user can even make notes and add personal information which would be available to other users.

The therapy phase (Fig 8) recommends appropriate drugs and vaccines for the infection. Side effects, effectively and probable interactivity of the recommended drugs are given as well.

![Fig 8 Recommended therapies for the diagnosis](image)

The final phase, microbiology, is also a learning tool for both the program and user. The user can query the program to make comparison on organisms. Suspected bugs from the earlier diagnostic phases can be examined as well.
5 DISCUSSIONS

From the preceding chapters it is now clear how invaluable computer aided diagnostic systems can be. After talking about their background and concepts, the task of medical decision making and case studies of some systems, this chapter discusses their strengths and weaknesses. It is quite obvious that CAD systems are an invaluable tool to all stakeholders in medical circles now and many years to come. An adequate measure to evaluation and improve their performance is very important and cannot be ruled out.

Generally, the field of internal medicine is so broad and complex that it will be difficult if not impossible to develop a CAD system for general clinical practice. This is evident in the CAD systems as they are narrowed to a particular area of medicine. An example is GIDEON being used for infectious diseases and even that is narrowed to the once caused by microorganisms. For example slow viral infection and surgical wound infections are not considered. Almost all CAD systems have scope issues which have lead to them being branded as lacking “common sense” by some commentators. They might not even realise that they have a limitation and would try to perform (diagnose disease) outside their domain of expertise (McCarthy, 1984).

A well designed and developed CAD system will perform better than a clinical expert on the level of scientific and mathematical analysis. However they cannot capture the creative aspect of diagnosis which expects call an ‘art’. A CAD system cannot decipher the emotions, afflictions and social issues of a patient. It takes clinical experience to carry out this part which unfortunately cannot be modelled into computer programs. This means that the system cannot function on its own as a medical consultant and would therefore have to be initiated and guided by someone (medical professional preferably). It is also essential that the knowledge base of the program should only be updated by a professional vested in the field in context. The reliability and accuracy of clinical input is very crucial for the efficacy of the system.

Looking at MYCIN, it is simple to use when the user is initiated. The nature of its interactive dialogue calls for an understanding of the domain in question by the user. The program being able to justify it conclusions is a plus and can even serve as a learning tool. MYCIN and rule based systems in general have a problem in capturing all relevant information into rules. It even becomes more complicated and confusing when the knowledge base of the program grows to the extent that the rules become inconsistent, unpredictable (Schwartz 1987) and conflicting with each other. To achieve reliable
results from the system, the author of the rules must anticipate the ways in which the rules will interact with each other.

As opposed to MYCIN where the rules are a combination of declarative and procedural knowledge (Miller et al 1994) INTERNIST-I had the advantage that its knowledge base contained purely clinical evidenced declarative knowledge in the form of intuitively appealing disease profiles. This advantage makes it quite easier to manage and maintain the knowledge base of the system even as it grows larger. The numerical attributes of each manifestation in a disease profile are novel and insightful and evades the problems of conflicts and inter dependencies as envisaged in MYCIN.

In spite of these added advantages INTERNIST-I had some pitfalls was well. Pople criticised the key elements of the diagnostic logic of the program. He maintained that focusing attention on the most highly scored hypotheses and their competitors have both pros and cons. The heuristic focusing method singles out a group of diseases which serve as indicators (from the scoring mechanism) given the patient data. Since the scoring scheme might lead the program to investigate on the basis of volume of data, relevant or significant data (which could be crucial to the final diagnosis) could be disregarded.

The sequential problem formation and problem solving model enables the program to focus and converge on a suitable conceptualisation of the medical problem. The disadvantage of this approach is that other (seemingly insignificant) data might be left behind the sequence. A clinical expert will consider all these little insignificant data and put them all together to make a sound diagnostic decision.

Another aspect of INTERNIST-I worthy of note is its problem formulation and decision strategy. Many experts have argued that this part is done in an ad hoc manner. Once a suitable differential diagnosis set has been recognized, it is likely that the correct diagnosis could be reached by eliminating all but one of the diagnoses in the set to serve as a default for further probing. Even though this strategy has been successful in solving complex clinical problems the difficulty is the inability of the program to consciously question the basis and validity of the elimination and decision processes. As mentioned previously, the program often generates incorrect task definitions at the outset, but this is compensated for by the ability of the program to reformulate the problem focus that might guarantee the emergence of an appropriate decision problem. There is no feature in the program to give the assurance that these will always happen and hence an incorrect diagnosis is probable.
GIDEON with its interactive graphical user interface is a further improvement on previous systems like MYCIN and INTERNIST-I. Updating its knowledge base is apparently an easy task even for the least expert in the field (caution must be threaded here). With the seamlessly integrated components the program can serve as both a diagnostic and a learning tool. An interesting feature of GIDEON and INTERNIST-I is their ability to link pathology and physiology with evidence clinical information to make successful diagnosis. Earlier systems like MYCIN lack this facility which has a telling effect on their accuracy. The major problem in developing a diagnostic system, for example an infectious disease diagnostics system like GIDEON, is the difficulty in obtaining reliable and accurate incidence data.

Disease reporting rate varies extensively between countries and even among different diseases within any given country. Moreover the program presupposes that the patient is a citizen or local resident of the country in question. Incidence data for foreign inhabitants such as tourists, expatriates etc may vary from those of the indigenous population. It is also possible that the country of acquisition (infection) may not match the country of residence.

Selection of discriminative clinical and laboratory parameters for the knowledge base is laborious and complicated by the fact that individual infections are quite similar (Berger, 2000). In some instances, more than one disease may be present, or clinical observations may be fictitious or unrelated to the present illness.

6 CONCLUSION

As of now a computer aided diagnostic system can not carry out consultations by itself. For optimal output it needs to be used and guided by a professional who understands it and its mode of operation. It is also clear that these systems, considering the huge amount of information it can hold, will be a great companion to health care professionals, researchers and the academia. A constant monitoring and evaluation of their performance and output is very essential.

For the development of the diagnostic system to be successful it is imperative that programmers and clinical experts work hand in hand. The objective is to create a mutually beneficial system that takes advantage of the strengths of both the user’s knowledge and the system’s abilities. This will immensely improve the performances of
both the user and the system.

The term “computer-aided diagnostic system,” should not be misunderstood as general-purpose, broad-spectrum consultation system. But a system which has a scope of jurisdiction and hence should only be utilised in that scope of context. For example a diagnostic system meant for diseases of the eye should not be applied to say diagnosing heart diseases. The pathological and physiological makeup of organs is different and distinct. Only programs relying on such reasoning would be able to cope with the enormous number of ways in which diseases can present, evolve, and interact with each other.

In designing, developing and maintaining a diagnostic program the validity and reliability of user input is very crucial to its performance. The slightest mistake in such information input into the system will lead it to make confusing and incorrect diagnosis and the consequences are priceless. Therefore only qualified personnel should be responsible for information input into the system.

Computer aided diagnostic systems have come of age. They are intended to check and guide clinicians to carry out their daily diagnostic work. Much work should therefore be done on efficiently integrating computer-aided diagnoses into the daily work flow of clinicians. The true potential of a future diagnostic system is one that will automatically link patient medical records and information in its knowledge base to make diagnosis.

REFERENCES


Berger SA, Blackman U. GIDEON; A Computer-Driven Bayesian Matrix For The Diagnosis Of Infectious Diseases.2000, Tel-Aviv.


Ledley RS, Lusted LB. Reasoning foundations of medical diagnosis. Science 1959; 130:9-21


Warner HR, Toronto AF, Veasey LG, Stephenson RA. Mathematical approach to medical diagnosis. JAMA, 1961;177:75-81