The *Iliad* Program: An Expert Computer Diagnostic Program

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ABSTRACT

An expert diagnostic system (*Iliad*) can prove useful to a family care physician as a personal consultant. *Iliad* can suggest diagnoses, advise regarding cost-effective work-up strategies, and explain relationships of findings to disease. Rearranging medical knowledge to perform such tasks is now possible with the help of a personal computer, which may soon be a vital element in every physician's office.

Key words: Computerized diagnosis; diagnosis; personal computers.

CASE STUDY

Jane Dunne is a 33-year-old woman who comes to my office complaining of shortness of breath, and I find on further questioning that she has had shortness of breath at rest and on exertion for several years. I enter this information into **Iliad** by typing in the keyword "dyspnea" and responding to a few questions that **Iliad** presents with respect to what brings on the dyspnea and the duration of the symptom.

Iliad displays two windows to me. One contains the data I entered organized in a hierarchical fashion, and the other is a list of possible diagnoses in order of decreasing probability that might explain these findings in a 33-year-old woman. Alpha-1 antitrypsin deficiency is on the list, and I ask **Iliad** how to pursue this diagnosis by selecting it with the computer's mouse. **Iliad** suggests that I ask the question, "Is there a previous history of chronic lung disease?" (particularly emphysema), and the patient responds that she has been diagnosed as possibly having emphysema in the past. So, now I do a physical examination and notice that there is decreased intensity of breath sounds on auscultation; there also appears to be restricted motion of the diaphragm by percussion, and the exploratory phase of the respiratory cycle is more than three times as long as the inspiratory phase.

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Iliad now tells me that there is a more than 95% chance that the patient has alpha-1 antitrypsin deficiency and suggests that the serum level be measured. This is a $40 test, but the simple data already collected make it highly likely that this test will be positive and will confirm my diagnosis.

The above scenario (Fig. 1) illustrates one of the roles an expert system can play in providing useful services in the offices of a busy primary care physician. **Iliad** is an expert diagnostic system that runs on a stand-alone **Macintosh** or **PC** with a knowledge base that covers 10 subspecialties of internal medicine. The system has been developed over the last 5 years at the University of Utah in response to a request from the Chairman of the Department of Medicine for a computer-based learning tool that could be used by third-year medical students during their clerkship on the medical service. The program has been an integral part of the medicine clerkship since July 1989 and is presently being used by 30 other medical schools. **Iliad** is marketed not only to institutions but to individual practitioners and students as well by a Utah company, Applied Informatics.

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How *Iliad* Works

The basic module in the **Iliad** knowledge base is a frame or table that relates a disease to its manifestations. These frames are of two types.

The first is the Bayesian frame, which represents a disease in terms of the frequency of each finding (symptom, sign, or laboratory values) in patients with the disease and in patients without the disease. The

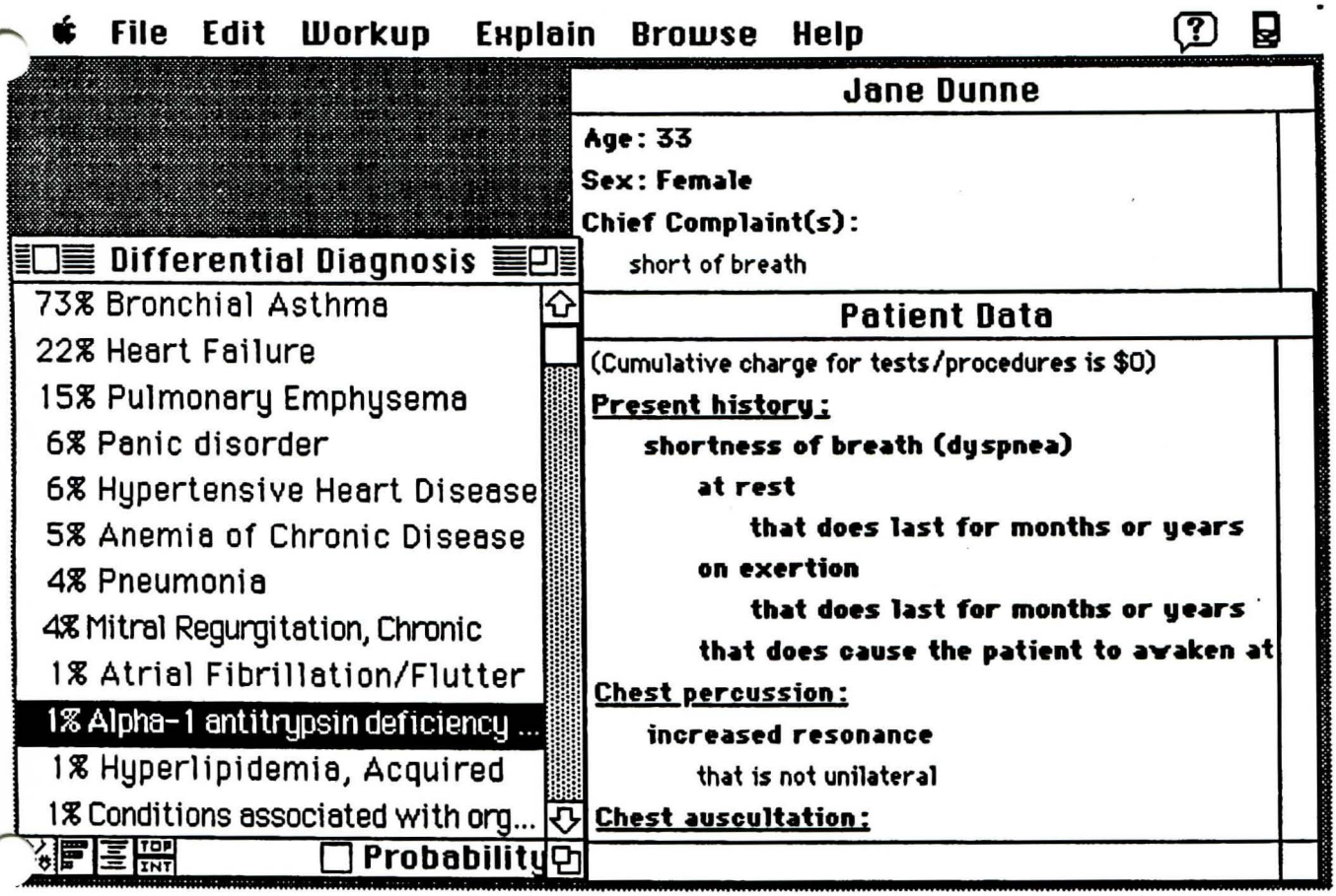

Figure 1. Patient work-up.

first statistic is called the sensitivity or true-positive rate. The other statistic is the frequency of that finding in people who do not have the disease but who are in the population of patients for which **Iliad** is being used (*i.e.*, the patients coming to the physician's office or the patient medical service of the hospital). The third statistic required by **Iliad** is the local knowledge of how frequently patients with each disease are encountered in the clinical setting in which it is being used. Once **Iliad** is told the status (presence or absence) of any findings in a particular patient, it will calculate the likelihood that the patient has each of the 650 diseases in its knowledge base and display them in order of decreasing probability.

The second type of frame used by **Iliad** is a Boolean or rule-based frame. This is used to describe intermediate clusters of findings that an expert uses to arrive at a diagnosis. Usually these clusters are entities defined by definitions or rules. An example might be a cluster called hypoxemia, which is defined by the presence of either cyanosis or an arterial Po_2 less than 60 mm Hg. Clusters such as this provide a means of representing

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the larger chunks of knowledge of information used by experts in making decisions and also provide a mechanism for using information about disease findings that are not independent of one another.

A medical expert system must be able to provide consultation even with partial information. In "working up" a patient, one never collects information on a given patient about all possible disease manifestations and it is necessary to make decisions on the basis of working diagnostic hypotheses at each stage of the process. This process of sequentially forming diagnostic hypotheses and deciding what observation or test to perform next to evaluate those hypotheses is the underlying model

incorporated in the **Iliad** diagnostic system.

Iliad's knowledge base is built through a process called knowledge engineering. In the Department of Medical Informatics at the University of Utah, we have a room with a large glass-topped oval table with four computer displays mounted under the glass. These displays allow convenient viewing of the output of either of two computers by anyone around the table. One-hour sessions are scheduled with an expert in a particular disease. At these sessions, knowledge about the disease is gathered from three sources: the medical literature, a large patient database, and the considered judgment of the expert. Once an initial version of the frame has been constructed, the expert observes its behavior by entering combinations of findings and can judge whether the frame appears to be over- or under-confident. After this step, the frame is compiled with the rest of the knowledge base and this expert and others can observe its behavior when data from real cases are entered into **Iliad**.

To develop the **Iliad** knowledge base to its current state, more than 7500 such 1-hour sessions have been conducted. These knowledge engineering sessions are used to refine and validate the knowledge base as well as to expand it to include other specialties. Knowledge engineering represents a major ongoing activity of the Department of Medical Informatics at the University of Utah.

Iliad has three modes of operation.

- In the **consulting mode, Iliad** asks the physician for the patient's age, sex, and chief complaint to initiate the patient work-up. The physician may enter findings (history, physical examination, x-ray, laboratory values, *etc.*) by entering one or more words (*i.e.*, cough) shown in Figure 2 and choosing from the terms presented by **Iliad** from its dictionary of terms describing disease manifestations. Alternately, the physician may directly enter **Iliad**'s dictionary, which is organized hierarchically, and work down the hierarchy to find the disease manifestation. For instance, from an initial menu, the user simply points to history, which

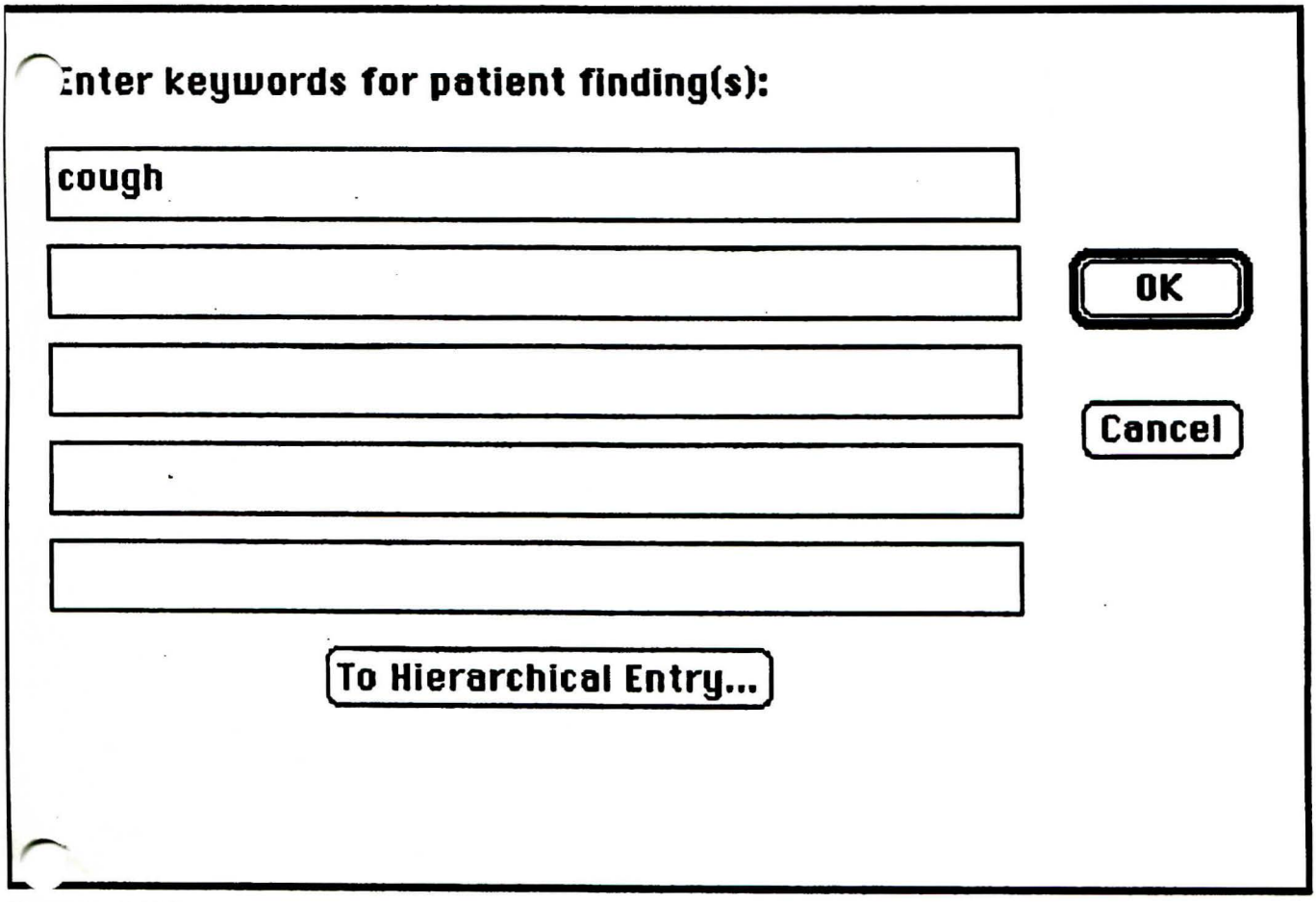
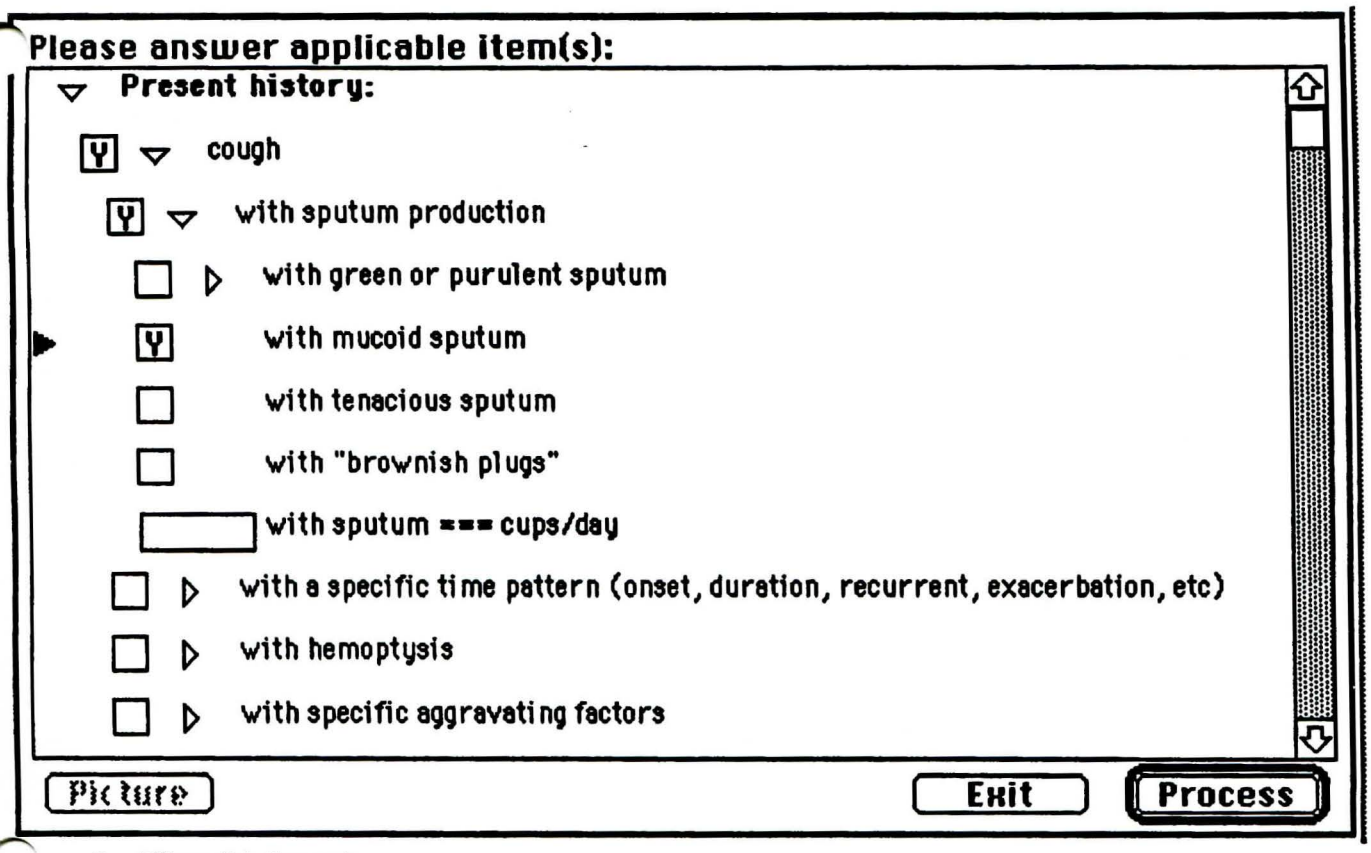


Figure 2. Initial menu.



gure 3. Differential diagnosis.

Once data have been entered . . . Iliad will perform calculations . . . and display a differential diagnosis.

immediately opens the next level of the hierarchy in which he or she chooses "present history," "cough" "with sputum production" that is "with scant and mucoid sputum." Each time an item is selected by clicking on it, the window expands to the next level and the entry can be made in a very few seconds. This interface between the physician and the computer is the key to determining whether the physician will take time to use the program.

Once data have been entered and a concept has been pursued to the level of detail the physician wishes to ter, **Iliad** will perform calculations on all of the mes that use these data and display a differential diagnosis (Fig. 1). At this point, the physician may proceed with the work-up or ask for explanations. To proceed with the work-up, the "add-data" option is selected from this pull-down menu and more data may be entered in the same way as the chief complaint. Alternately, the physician may ask **Iliad** what is the best thing to do at this stage of the work-up. **Iliad** will calculate which of the more than 6000 questions, physical findings, or laboratory values would provide the most information on the basis of what it currently knows about the patient for the least cost. Each item in **Iliad**'s dictionary has a cost associated with it. Because of the low cost assigned to history and physical examination findings, **Iliad** will not choose an expensive test early in the work-up of a case.

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The user may ask for an explanation of any disease or any finding. By the user pointing to a finding on the

record, a window will appear listing the diagnoses that st explain this finding in this patient in order of decreasing likelihood. To explain why **Iliad** is considering a particular diagnosis, the disease may be selected from the differential diagnosis by the user pointing to it. The logic used to arrive at the current probability listed for that diagnosis will be displayed in the context of the other findings pertinent to making this diagnosis. To gain more insight into the relationship of the disease to its findings, the user may pursue, independent of the work-up of this particular case, a "what if" analysis by quickly selecting combinations of findings in a frame and observing what happens to the probability of disease (just as the expert did when he/she created the frame).

- In **Iliad**'s **critiquing mode,** the physician enters his/her working hypothesis by entering a keyword(s) or by selecting directly from **Iliad**'s disease hierarchy. **Iliad** then asks for the findings needed to confirm or rule out the selected disease. The disease frame may contain other frames representing intermediate decisions, such as hypoxemia. **Iliad** asks the user whether these frames are true and if the physician says yes to a particular cluster or subframe, **Iliad** will request information about the findings needed to make that frame true. Work-up in this particular mode proceeds very rapidly and results in a collection of data that either confirms and documents the physician's initial diagnosis or suggests other more likely explanations for the findings entered. The user may switch back and forth between critiquing and consulting at any stage in a patient work-up.
- The third mode in which **Iliad** may operate is called **simulation** and is designed to give the user experience in solving realistic diagnostic problems. In this mode, **Iliad** provides the user with information about a patient upon request and then asks the user to generate a working differential diagnosis at each stage of the work-up. The user must indicate which diagnosis is being pursued with each request made for new information. At each step, **Iliad** evaluates the user's ability to draw the right conclusions from the data collected and to pursue the most cost-effective approach to arriving at the diagnosis. An audit of user performance is maintained and can be displayed in graphic or tabular form at any stage of the patient work-up.

Simulated cases may be made in several ways. Any real case entered in the consulting or critiquing mode can be converted to a simulation. **Iliad** can also generate simulations automatically for any disease because the knowledge base is represented in statistical form. For example, once a disease is chosen by **Iliad**, it compares the true-positive rate or sensitivity of each finding to a random number between 0 and 100. If that random number is less than the sensitivity of the finding, that particular finding is recorded as present in the record of the simulated patient. Thus, each case is statistically appropriate but is likely to be different from the next case of the same disease generated in this mode. Simulations of patients having more than one disease may be used to make more challenging cases.

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Experience with *Iliad*

Iliad has been widely used as a training tool at Utah and many other institutions. An evaluation of medical students using **Iliad** has shown that their ability to diagnose diseases is improved for diseases they have worked up with simulated cases. They acquire more of the data needed to confirm the diagnosis and also request less irrelevant and expensive test results. At other institutions, **Iliad** has been used to train medical students through all 4 years and has also been used as a tool for the continuing education of residents and practicing physicians.

Experience with **Iliad** in a consulting mode has been more limited. Eight physicians in southern Utah volunteered to try **Iliad** for a few weeks in a primary care setting. Although they found it interesting, most of them thought the data entry process was too time consuming for everyday use in a busy practice. This was 2 years ago. Since then, we have attempted to improve the data entry in three ways.

. . . medical students using* Iliad *[have improved] ability to diagnose diseases. . . .

First, we have made data entry much simpler so it does not require opening a new window at every step in the hierarchy. An example of this is shown in Figure 3.

Second, because much of the time the physician has a good idea early in the work-up as to the probable diagnosis, we have added the critiquing mode. This allows the physician to focus immediately on the data

required to confirm or deny the working diagnosis he/she has entered.

Third, we have developed a patient version of the history items in **Iliad**'s dictionary. This allows **Iliad** to interact directly with the patient in the following way. An office nurse or secretary can initiate the program by entering age, sex, and chief complaint. **Iliad** will then proceed to form hypotheses and, using its algorithm to determine what best to do next, ask questions to test those hypotheses. This process assures that the questions asked are relevant and will usually result in a useful differential diagnosis and patient history that can be presented to the physician in "doctor language" for his/her review.

Summary

An adequately documented diagnosis forms the basis for rational treatment and prognosis because it is the link around which we organize and communicate medical knowledge. Outcome research that is vitally needed to answer key questions facing medicine today regarding alternate forms of treatment will only be possible when our outpatient records contain such documentation in electronically readable form. Programs like **Iliad** that demonstrate an attempt to standardize diagnostic criteria in a form that can be used in the management of real patients represent an important step toward this goal. ⊞

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