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The WIC Advisor: A Case Study in Medical Expert System Development

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The knowledge acquisition methods used in creating The WIC Advisor comprise a beneficial case study of several traditional techniques. Protocol analysis, question/answer listing, knowledge acquisition room selection, prototyping, focused interviewing, multiple expert selection, direct questioning, audio-tape transcription, diving the domain, role-playing and teach back were employed [4,5].

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THE WIC ADVISOR: A CASE STUDY
in Medical Expert System Development

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Abstract

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1 Introduction

The Women, Infants, and Children (WIC) nutrition clinic of Madison County, Illinois, provides nutritional assistance to qualifying women and children through a federal and state funded program. Clients of the WIC program are low to no income families. Pregnant women and mothers with infants and children under five years of age are referred to the clinic by social agencies or doctors. At the clinic, these women are interviewed to determine their eligibility for nutritional assistance. The women or their children must show certain risk factors to qualify for the program. Such factors include weight problems, anemia, and a destitute financial situation.

To understand the services provided by the clinic, it is helpful to follow a client on her first visit to the Madison County WIC clinic. After she is referred to the clinic, the mother or mother-to-be makes an appointment for screening. Upon arrival at the clinic, the client fills out a substantial amount of paperwork to describe her risk factors and financial situation. A WIC staff member then reviews this paperwork with the client, and determines whether she is eligible for WIC assistance.

If the applicant proves eligible, she completes diet history forms for herself and her family. A WIC nutritionist then reviews the completed forms with the client. During this review, the client is encouraged to ask diet-related questions, and is given nutritional information. Next, the client and any children are examined by a nurse. Part of this examination is a physical and part is a question-and-answer session with the mother or mother-to-be about health problems or concerns. In the last step of the WIC process, the client meets again with the nutritionist where she is given diet suggestions, milk and food coupon packets, and a schedule of future visits.

Just before the start of our development efforts, the WIC clinics in Illinois were informed that they would be receiving a computer system to help automate the eligibility paperwork and the coupon distribution. The hardware was to be based on personal computer nodes and a server. There were to be several changes to the clinic environment

resulting from this pending automation. Instead of the Madison County WIC clinic continuing to travel to as many as four locations a week (to set up in the communities where the clients are living), it would consolidate into two main locations. The computers, 386-based IBM PS/2s, would be permanently installed at the main locations.

The new computer system would alleviate many tedious paperwork tasks for the WIC clinic staff. After consulting the WIC nurses, however, we suggested that the computer might provide even more assistance than planned by the state of Illinois. This increased assistance would be provided by an expert system. WIC staffers were concerned that most of their clients had little or no practical medical training, were prone to illiteracy, and had minimal access to medical information. The concept of an expert system that WIC clients could access for medical and nutritional information appealed to the nurses.

With this expert system in place, the client would call the Madison County WIC clinic and describe her questions or problems to a WIC staff member. In turn, the staff member would consult the expert system, which would dispense the appropriate advice. The typical system user would be a lactating (breast feeding) mother, a pregnant woman, or a parent calling about a problem with her child or infant.

The next section of this paper will explain the knowledge acquisition process used to build this expert system—called The WIC Advisor—for the WIC clinic in Madison County. Section 3 reviews Texas Instruments' Personal Consultant Easy, the PC-based expert system shell used to create The WIC Advisor. Section 4 summarizes The WIC Advisor project, and provides insight into potential future work with The WIC Advisor expert system.

This system was built during a one-semester project course in Knowledge Engineering at Washington University. The first three authors made up the project team which developed the system.

2 Knowledge Acquisition

2.1 Techniques

The knowledge acquisition methods used in creating The WIC Advisor are not novel, but serve as an informative case study on applying several traditional knowledge acquisition techniques. The techniques used were protocol analysis, question/answer listing, knowledge acquisition room selection, prototyping, focused interviewing, multiple expert selection, direct questioning, transcription, dividing the domain, role-playing, and teach-back.

AI literature recommends using protocol analysis when attempting to analyze a domain expert's general problem solving approach [4,5,9]. This method is typically not an interactive process, but rather one in which an expert explains his actions as he proceeds with his problem solving techniques. Given our lack of prior knowledge of how a WIC clinic functions on a daily basis, we decided that protocol analysis would be the appropriate tool to begin our knowledge acquisition.

Another method we used was development of a preliminary question/answer list provided by the experts, based on the most common problems/solutions in their domain. This method served as an excellent lead-in to our focused interviews.

We were very careful in choosing the environment for our focused interviews. In McGraw, a knowledge acquisition room is described in great detail [5]. We felt that this particular room would be too sterile and intimidating for our experts. Instead, we chose

a hospitable, quiet environment that was effective in both setting the experts at ease and helping us avoid misunderstanding instructions and uncooperative attitudes (problems that traditionally plague knowledge engineers [3]).

We used an eleven-rule prototype to demonstrate to our experts how the system would work. Prototypes provide experts with an example of expert system technology applied to their own domain, acquainting them with what the knowledge engineers hope to accomplish and spurring their interest in the project [8].

A major portion of our knowledge acquisition process was based on focused interviews with multiple experts. We used direct questioning in these interviews to expand upon previously gained knowledge. Allowing the experts to confer upon domain issues provided valuable insights; i.e., clarifying issues left unresolved from the question/answer list. We also audiotaped and transcribed the focused interviews to avoid losing information. This method provided benefits that outweighed the tediousness of the task. In writing our rules for the system, we found details in the transcription that were not noted during the interview, but proved useful in building a robust system.

Based on the interviews and the question/answer list, we were able to divide the domain into three subdomains. Each project team member took responsibility for a separate subdomain, and focused subsequent questions to the experts accordingly. In order to verify previously gathered information, we used the techniques of role-playing and teachback. These two techniques not only clarified existing rules, but also allowed us to extend the knowledge base.

The following is an account of the knowledge acquisition process used in developing The WIC Advisor.

2.2 Informal WIC Clinic Visit

The first step in building The WIC Advisor was to gain an overall understanding of the WIC clinic's everyday operations by making an informal clinic visit. On this visit, we used the protocol analysis method. By playing a passive role, we absorbed as much information as possible by observation.

The informal clinic visit began with the head WIC nurse "assigning" us to a new WIC client: a mother with an infant. We followed the mother through each stage of an initial WIC visit, observing all interactions between the mother and the WIC staff. The "experts", consisting of nurses, nutritionists, and clerks, occasionally stopped to explain their procedures. They also provided copies of available forms and informational brochures disseminated by the clinic.

The protocol analysis method provided a broad understanding of the basic WIC operations from which future interview questions were generated. At this point we were able to reduce the initial WIC visit to four primary stages: certification, dietary questioning, nurse's examination, and nutritional education. The identification of these stages, along with other supporting information, suggested several expert system applications. Expert systems could have been built to act as a health advisor, a nutrition advisor, or as a WIC certification assistant. Upon further investigation, however, we learned that the clinic may already be receiving software capable of handling the nutrition advisor tasks. In addition, we were informed that the state of Illinois did not want the certification process automated. The state felt strongly that the "human element" of this procedure should remain intact. From such information, we chose the health advisor domain for The WIC Advisor.

2.3 Expert Selection and Question/Answer List Development

Having refined the scope of the domain, our next task was to select the individuals whose expertise we were attempting to capture. The obvious experts were the WIC nurses. We asked them to compile a list of questions most frequently asked by clients. This list proved very important in the knowledge acquisition process. First, it divided the health advisor domain into three different categories: lactating mothers, pregnant women, and infants/children under five years of age. Secondly, the information on the question/answer list was specific enough to enable development of an eleven-rule working prototype in Personal Consultant Easy. Thirdly, it provided the basis for focused interviews and other knowledge acquisition from Madison County WIC nurses.

2.4 Initial Focused Interview

Having obtained a significant amount of background information, we conducted a focused interview as the next stage of our knowledge acquisition process. In preparation for this interview we chose two nurses as our experts and discussed possible locations for the interview. Since access and time constraints were the biggest problems knowledge engineers had with experts [3], we wanted to avoid these problems. Also, we wanted an atmosphere conducive to clear, uninhibited dialogue. By treating the nurses to dinner in the privacy of a banquet room at a local restaurant convenient to them, we established the appropriate environment for an initial focused interview, while setting the experts at their ease.

We provided the WIC nurses with information on expert systems in general and an introduction to the objectives of The WIC Advisor. In order to show the nurses how their information would be used, we demonstrated the aforementioned eleven-rule prototype of The WIC Advisor using a laptop Toshiba computer. Direct questioning regarding the question/answer list took place during dinner. We audiotaped the entire discussion to avoid losing interview details. Although the experts were initially intimidated by the recording device (a problem reported by other knowledge engineers [8]), they seemed to forget about it within minutes.

2.5 Post-Interview Analysis

In the first interview, the WIC nurses appeared relaxed and enthusiastically offered a wealth of valuable information. The prototype demonstration seemed to impress the nurses, as well as to alleviate some of their apprehension about using a computer. An important facet of this session was that two nurses were interviewed. Questioning more than one nurse provided a more informed and reliable source for The WIC Advisor. Each nurse seemed to help the other, either by reinforcing or by constructively criticizing the other's statements on solving a given problem. The problem of conflicting experts, rarely reported in general [3], was also not a problem in this focused interview.

The interview enabled us to divide the project domain into three subdomains: lactating, pregnancy, and infants/children under five years of age. Each team member developed one subdomain of the knowledge base. This division allowed more effective concentration on a manageable portion of the entire domain. Thus, each "subdomain developer" could better prepare for questioning the experts and building rules.

Recording and then transcribing the interview was very important to the knowledge acquisition process. Many of the details, side comments, and facts uncovered during

transcription did not appear in our notes. These details *et al* proved crucial in filling subtle but salient knowledge base gaps. We applied the knowledge gained from this interview in constructing the questions for our next interview and in adding to our evolving prototype.

2.6 Second Focused Interview

The next stage of the knowledge acquisition process was another interview with WIC nurses. Because of our success with the first interview, we chose the same restaurant as the interview site. Two different WIC nurses were asked to participate. Again, the entire discussion was audiotaped. During this interview, two different knowledge acquisition techniques were used: role-playing and teachback. Having developed a set of rules pertaining to the three subdomains (lactating, pregnancy, and infants/children) within The WIC Advisor knowledge base, we had the nurses act as WIC clients asking us for advice. The role-playing approach proved useful in several ways. First, it verified the answers which had already been incorporated into the knowledge base. Secondly, it allowed the nurses to expand upon our responses, thereby “fleshing out” the knowledge available for The WIC Advisor development. Finally, it provided another means for evoking new ideas from the nurses. The experts divorced themselves from the role of nurse, in which they attempt to remember everything heard from a patient, and placed themselves in the patient’s position. As patients, they were thinking of problems patients might experience. The nurses were then able to generate new ideas that neither set of nurses expressed previously.

After the role-playing session, we used the teachback technique to explore rules in our knowledge base that had not been covered in the role-playing episode. Through the teachback method, the nurses were again able to verify the correctness of the rules, as well as to expand upon them. We finished the session in focused interview mode, filling out ambiguous areas in the knowledge base. Having completed the second interview with WIC nurses, we once again transcribed the interview and formalized the knowledge acquired.

2.7 Clinic Presentation

The final step in the knowledge acquisition process was to have all the nurses in the Madison County WIC system test the 118-rule knowledge base. They appreciated its ease of use, since many of them had been apprehensive about the new computer system that the state of Illinois was installing. The nurses felt that the expert system was not intimidating, and were impressed by its breadth. Nurses that had not acted as experts tried the system using problems that clients had presented recently. These nurses were pleasantly surprised that the system provided useful answers. One nurse found a conclusion that she felt should be worded differently. When other nurses agreed with this finding, we corrected the wording. Another nurse suggested two additional ailments that she had had to deal with lately. Since the other nurses felt that these ailments were not vital, those ailments were not added to this version of the system.

2.8 Knowledge Acquisition Summary

We conclude that the knowledge acquisition methods used in creating The WIC Advisor comprise a beneficial case study of several traditional techniques. Important factors in the success of this expert system were the selection of a limited diagnostic domain, and the choice of multiple experts who worked well together. Personality factors, while seldom mentioned in the literature, were important to the success of the system. At no point

during the knowledge acquisition process did any of us experience a personality conflict with each other or with an expert.

The setting for the interviews significantly enhanced the process. The sequence for applying the knowledge acquisition techniques was not irrelevant: Starting with a protocol analysis of the WIC clinic daily operations, then building on the question/answer list in preparing for the direct questioning sessions gave us a deeper understanding of the domain. Dividing the domain into manageable subdomains proved valuable when constructing the knowledge base rules for review in the role-playing and teachback sessions. Transcription of the audiotapes helped us add details to the knowledge base. Finally, by demonstrating the system to the nurses before final delivery, we were able to make final corrections to the expert system.

3 The WIC Advisor on PC Easy

The WIC Advisor, containing 118 rules, was developed using Texas Instruments' Personal Consultant Easy (PC Easy). There were disadvantages to using PC Easy; however, the advantages justified its selection. The resulting version of The WIC Advisor was designed for use as a "practical" expert system, with a logical questioning order.

We selected PC Easy for The WIC Advisor development based upon a recent survey of PC-based expert-system shells which gave PC Easy a high rating [1]. Although the shell worked well overall, we did encounter some difficulties. We found that we could not renumber the rules after making rule modifications or deletions. We also were unable to execute development versions of PC Easy expert systems while PC Easy run-time software was installed on the IBM PS/2. Most importantly, we were unable to combine separate knowledge bases into one. Finally, we found that title screens cannot be used in run-time versions of PC Easy expert systems. The advantages to PC Easy, however, far outweigh these difficulties. We found that the shell allows for easy construction of rules since it prompts developers to write the "if" and "then" clauses of each rule. The shell allows expert system end users to ask WHY and HELP in response to any question posed by the expert system. The end user can also ask HOW any conclusion offered by the expert system was reached. Finally, the session reporting capabilities of the shell are excellent.

This shell allowed for the development of an expert system that has

1. a questioning order which matches the natural flow of human consultation,
2. a questioning pattern which is not random,
3. a focus on key factors early in the consultation,
4. capabilities for documenting consultation sessions.

Expert systems without such questioning traits are theoretical successes but practical failures—they appear to meet the requirements of a good expert system, but nonetheless fall into disuse [7]. The WIC Advisor first asks for the key factor in the consultation: "Is the patient a child, a pregnant woman, or a lactating mother?" From there, The WIC Advisor forces the user to select from the list offered, thereby narrowing the search field further. Such narrowing also makes it clear early in the session whether the system will be of use to the client. Only after these two major choices are made does The WIC Advisor begin with "yes/no" type questioning. At this stage of the consultation, such questioning

is not random but quite direct: A WIC solution is reached within three questions at most. While purely a backward-chaining system, The WIC Advisor displays forward-chaining characteristics by proffering lists at the outset of a consultation. In addition, PC Easy allows for the user to review the answers given to The WIC Advisor questions, to show the user how The WIC Advisor arrived at a given conclusion.

The version of The WIC Advisor delivered to the Madison County WIC clinic consists of 118 backward-chaining rules. Three separate knowledge bases comprise The WIC Advisor. Of these three knowledge bases, the one concerning children's problems is the largest, consisting of 67 rules. Next is that for pregnant women, consisting of 33 rules. The 18-rule lactating knowledge base is the third knowledge base in the group.

4 Conclusions

The WIC Advisor does not extend the state-of-the-art in AI, but is the viable expert system resulting from a case study in knowledge acquisition. The WIC Advisor was written with the close cooperation of the WIC nurses in Madison County, so that the expert system might be of use to them upon its completion.

Many of the expert systems now in use are not extremely sophisticated from an AI perspective. Rather, they perform simple tasks. The WIC Advisor underscores the notion that "expert system technology may have more to offer in helping people organize their thoughts than replacing thinking people" [2]. The nurses who helped build WIC Advisor's knowledge base commented that the program might aid in the dissemination of more consistent advice for given problems. Reinforcing this comment is a quote from the aforementioned survey of expert system shells [1]:

While the early successes in expert systems involved high-level experts being debriefed of a lifetime of accumulated knowledge, today's expert systems are appropriate for any administrative task where the number of factors involved is finite but large enough to make it hard to remember all of them at once....The expert systems [reviewed in the survey] offer the prospect of faster and more efficient decision making—something every department in every company can use.

Indeed, The WIC Advisor has a place not within state-of-the-art artificial intelligence, but with the low-tech expert system "applications that are finally emerging in droves from Corporate America" [6]. Such applications are actually put to use; we have striven to ensure that the same is done with The WIC Advisor.

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