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Intelligent Agent Model for Remote Support of Rural Healthcare for the Elderly

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Abstract – With the aging population, the number of individuals requiring long-term care is expected to dramatically increase in the next twenty years, placing an increasing burden on healthcare. Many patients are admitted to assisted living facilities at a fairly early stage due to their inability to perform normal daily living activities. The purpose of this study is to determine if the use of technology for both monitoring and intervention can permit elderly patients to remain in their homes for longer periods of time with the benefit of the comfort of familiar surroundings while at the same time reducing the burden on caregivers. In addition, remote access to healthcare can improve monitoring of the patient's physical and mental condition and involve the patient in his or her own care. The home monitoring and intervention system is based on intelligent agent methodology developed by the authors.

Keywords: – Home monitoring, agent systems, remote sensing, eldercare

I. Introduction

With the aging of the baby boom generation, the average age of the US population is rising, with a sharper increase expecting for the next two decades [1]. Statistics show that a large percentage of healthcare dollars are directed to elder care, putting an increasing burden on society at a time when healthcare costs are already rising at alarming speed [2]. Issues associated with healthcare for the elderly need to be addressed within a short timeframe and with innovative solutions. The majority of healthcare costs for an individual are associated with care at or near the end of life [3].

Fifty years ago many healthcare needs were addressed by the family physician who regularly made house calls both to tend to the sick and to maintain contact with patients to determine how they were doing. With the advent of technology, home visits became less useful because the physician did not have access to new diagnostic technologies that were only available at centralized locations. At this time, the delivery of healthcare shifted to the current status quo, in which patients travel to their primary care physician's office for check-ups and treatments. The typical physician's office contains diagnostic devices. Patients requiring further tests are referred to laboratories, imaging facilities, and hospitals. While technology has vastly improved diagnostic capabilities as well as offering new treatment modalities, it has in many cases removed the personal connection between physician and patient, and has deprived the physician of the ability to observe the patient in his or her own surroundings [4]. In the process, the cost of medical care has risen to pay for office support staff, instruments, technologists, and complex billing procedures. In the twenty-first century, it is time to ask how technology can be used to provide the highest level of medical care at an affordable cost and for the convenience of the patient. One part of the solution is to use technology to deliver healthcare to the home as an automated form of the house call.

A home health system based on agent-assisted remote interventions is described that has the objective of keeping elderly patients in their home environment as long as possible [5]. The design consists of both monitoring and intervention to assure the safety of the patient as well as his or her state of well-being. An added advantage of this approach is that the necessity of costly long-term care is delayed, with benefit to patient and society alike.

The project is based on a healthcare system that is located in an urban area (Fresno, California) but serves a large surrounding rural area. The heterogeneity of the population is evidenced by the ethnic make-up of Fresno County's population, composed of approximately 350,000 Hispanic, 320,000 white, 40,000 Black, 6,000 American Indian, 63,000 Asian, 700 Pacific Islander, 1,500 other and 19,000 multiple races (2000 U.S. Census).

II. Problem Definition

The elderly population in rural areas often faces a number of challenges in obtaining healthcare. Access is limited by distance and lack of transportation. Many rural patients are also socially isolated and often live some distance from family members and friends. The intent of the project is to provide support in terms of medical evaluation and intervention as well as social support with the intent of allowing patients to function in their home environments as long as possible. Examples include the use of technology to interact directly with the patient and/or caregiver [6], in-home devices as well as telemedicine interventions [7], and use of the Internet as a source of information both for education and support [8, 9]. The first goal is to permit remote monitoring by a caregiver or medical professional. The second goal is to intervene directly by remotely providing information or by making suggestions via the integrated system. One benefit of this design is that common problem behaviors that may affect ability to live at home can be targeted individually. The system consists of three distinct applications:

A. Remote health monitoring
B. Interventions to support daily activities
C. Social support

III. METHODOLOGY

Intelligent agents have been used successfully in a number of applications including healthcare delivery [10], providing reasoning capabilities through a variety of methodologies including artificial intelligence based models, Bayesian models, and neural networks, as well as other reasoning paradigms. An agent system developed by the authors integrates specific tasks of this application [11]. Intelligent agents extend the idea of hybrid systems in which differing approaches are combined to reach a comprehensive decision [12]. It has the advantage of encompassing a wide-ranging combination of information types and different paradigms that can be adapted to new problems without agent software modification.

A. Intelligent Agent Structure

Fig. 1 shows the intelligent agent configuration. The principal components of the control structure are the task manager and the communications interface. The task manager breaks the problem into subtasks that are then directed toward the appropriate agents and also combines results from agents, including the client, for the overall response to the problem. The communicator presents input to each agent in a form that it can understand and interprets output from each agent for other relevant agents. The remainder of the structure is contained in the agents themselves. Components in the illustrated system include a knowledge-based component that incorporates expert-supplied rules using the authors' EMERGE inference engine, a data-based component based on the Hypernet learning algorithm, and a signal analyzer to interpret biosignals and sensor output. In Fig. 1 the agents are defined by the methodology. Agents for specific application can also be defined by function, as illustrated in the following section. Function agents each employ one or more methodological agents to achieve their goals.

B. Intelligent Agent Functions

The task manager and communicator serve vital roles in the system design. The task manager assigns tasks to appropriate agents and coordinates results by using Meta rules and symbolic processing to assign tasks and reach an overall conclusion. It communicates with the human user, who is also considered to be an agent and coordinates activities with both function-based and methodology-based agents. The Meta rules are designed specifically for each application in conjunction with domain experts. The task manager interacts with both function-based and methodology-based agents as demonstrated below.

C. Meta Rules

Meta rules are used to direct a task to the appropriate methodological agent. For example, a decision will be directed to the most relevant methodological agent or agents. Consider the Meta rule in Step 1 of Figure 2. Each of the three hypotheses must be evaluated. In order to determine if the ECG is abnormal, first, the signal analysis analyzers must be invoked.

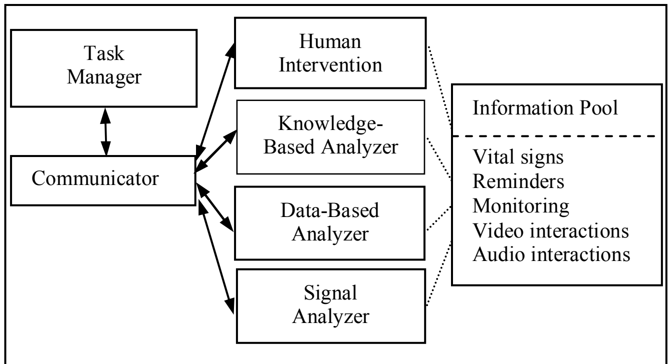

Fig. 1: Computational Architecture for Decision Support

Results of these are then passed to the neural network model to combine multiple parameters. The results are then passed to the Meta rule, to be combined with the other hypotheses.

Step 1 shows the initial Meta rule, step 2 shows the signal analysis components, and step 3 shows the neural network classification. Step 3 then sends the results to the Meta rule in step one for final evaluation. Step 1 shows two different components that contribute to the ECG evaluation, the first on which is the number and type of abnormal beats and the second of which is a summary measure. These numerical results are combined in the feature vector $\mathbf{x}_1$. The classification algorithm shows $D(\mathbf{x_1}) > D(\mathbf{x})$ indicating that the patient has an abnormal ECG pattern. This numerical value is translated into "abnormal ECG" presence and sent to the knowledge-based model in step 1 where it is used in a rule combining it with other information

Other relevant clinical parameters are evaluated by the symbolic agent to determine the type of action that is necessary. The arrow in Figure 2 illustrates that antecedent 1 has been handled. The next task is the evaluation of antecedents 2 and 3, confirmation of blood pressure through remote sensing and confirmation of perspiration through video feedback.. The task manager tracks tasks as a last-in, first-out stack (LIFO). The blood pressure (BP) antecedent is determined directly from a ring sensor that is monitoring remotely, and the sweating antecedent is determined from video monitoring. If the rule is substantiated then the process switches from the decision mode to the intervention mode, as shown in the next section.

D. Communicator

The communicator is invoked by the task manager to provide translations that allow data-based agents to communicate with symbolic-based agents. The task manager sends information to the translator when necessary to make transitions between symbolic and numeric information. For example, the neural network is presented with a feature vector $\mathbf{x}_1$ where $D(\mathbf{x}_1)$ is $> D(\mathbf{x})$ indicating that the patient has an abnormal EEG pattern. This numerical value is translated into "abnormal EEG" presence or absence and sent to the knowledge-based model where it is used in a rule combining it with other information Other relevant clinical parameters are evaluated by the symbolic agent to determine the type of action that is necessary, as illustrated in Fig. 2.

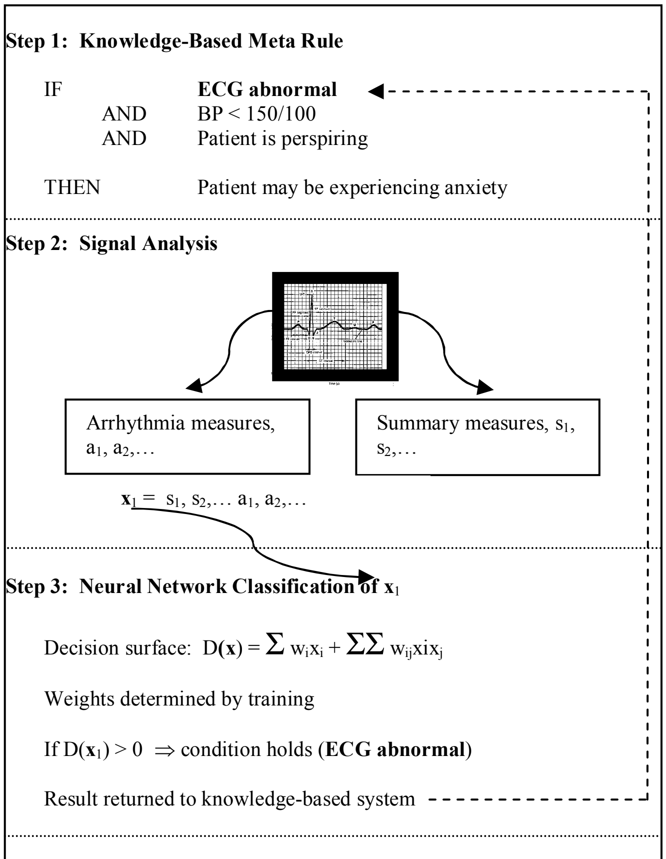

Fig. 2: Translation from Neural Network Output

IV. SYSTEM DESIGN

Agents were defined above in terms of methodology; they can also be defined in terms of function. Table I lists the agents by function. Note that software and human agents are both listed, along with the devices with which they interact. Personal care, interaction with family and community, and anxiety are three general problem areas all of which tend to lead to patient institutionalization, either by disability leading to patient health and safety issues or by increased caregiver burden leading to burnout [13]. The agent system addresses each of these. While general interventions are defined for all patients, the model also addressed individual patient needs. The reminder agent is an example of a specific function providing reminders occurring at fixed times and/or triggered by surveillance cues.

The agent system supports three distinct areas by providing virtual house calls, automated support for daily living, and online support for social activities. The functional level of the patient is a factor in determining which aspects of the system are suitable. A re-evaluation must be done periodically to assure that the specific implementation for each patient is meeting the prescribed goals.

Table I: Agents and Devices

Agent	Type	Devices
Reminder	Software	Television, telephone, sensors, video camera
Communication	Software	Wireless network, computer, television
Surveillance	Software	Wireless network, vital sign monitor, video camera
Patient	Human	Television, camera, telephone, video camera
Caregiver	Human	Computer, Internet, telephone, video camera
Medical Professional	Human	Computer, Internet, telephone, video camera

A. Remote Health Monitoring

Remote health monitoring can be accomplished using readily available devices. The simplest application is a telephone call from a medical professional who asks questions that would normally be asked in an office visit. Health data can also be transmitted using regular telephone lines. This approach has been useful in monitoring the status of diabetic patients [15]. Information from home monitoring devices, including electrocardiogram records, spirometer, oximeter, and blood pressure monitor can also be transmitted for analysis [16]. The use of a videocam with a television or home computer with ISDN or cable connections can permit visual supervision of the patient. Frequent contact with a medical professional lends comfort to the patient and permits direct participation in his or her healthcare.

B. Interventions to support daily activities

Table II summarizes agents defined by problem area dealing with the support of daily activities. The intent of these interventions is to help elderly patients in performing tasks as well as relieving burden from families who live some distance away from the patient. Table II also provides a format for evaluating the degree of success of the intervention.

C. Social Support

Social support for the rural patient can be provided through a number of resources, including telephone and/or Internet support groups, video recordings from family members and friends, and online resources for education. A recent study has shown that Internet chat groups for rural cancer patients contributed not only to their general health, but also to their emotional state [17]. The online access to the latest healthcare information provides resources that are generally not available in the rural community.

V. CONCLUSION

The objective of this project is to determine if monitoring and interventions based on the use of readily available technologies can assist patients in maintaining independence as long as possible, while at the same time reducing the burden on caregivers as well as reducing costs incurred by the necessity of using long-term care facilities. In addition, the system provides for remote monitoring of the status of the patient to determine if medical intervention is required.

Table II: Agent Tasks Defined by Problem Area with Examples of Interventions

Problem Area	Intervention	Evaluation Parameters
Personal care Taking medications Meal preparation Bathing	Alerting to initiate tasks (meal preparation) Alerting to complete tasks (wash dishes) Sensing job completion (stove turned off) Alerting if not completed	Rate of task completion Maintenance of weight Number of meals consumed
Interaction with family/ community Disorientation Inability to keep appointments Repeated phone calls to family members	Morning alerting system Calendar displays,web updatable by family Calendar alerting system based Sensing repeated dialing Alerting for repeated phoning Pre-recorded video messages, web updatable	Ability to keep phone appointments with investigators Number of repeated phone calls to family members in designated time frame
Anxiety	Heart rate monitor alerts Music/ recorded video message from family	Length of elevated heart rate pre/post- IA implementation
Individual Problems	Individualized Intervention	Individualized Evaluation Parameters

The need for home-based support for elderly patients is increasing dramatically and will continue to increase with the shifting of demographics toward an elderly population. Keeping patients in their own homes as long as possible has a number of direct benefits to the patient, including living in familiar surroundings and maintaining a feeling of independence. The intervention devices also have the benefit of keeping the patient active both mentally and physically, both of which have a positive effect on mental decline. From the caregiver perspective, some respite may be achieved from reducing the number of telephone calls and visits that must be made to the patient, while also providing the facility to monitor the patient from a distance, thus reducing stress by being able to check on the patient. From the society point of view, home care greatly reduces the high cost of assisted living facilities, a cost that is currently not covered by either medicare or normal private health insurance. It also reduces the need for nursing support that is currently in short supply. Work is continuing to determine which aspects of the system are most beneficial according to the following criteria: physical health, emotional health, and functioning level as determined by the Folstein scale for cognitive functioning [18].

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