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The Independent LifeStyle Assistant™ (I.L.S.A.): Deployment Lessons Learned

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Abstract

The Independent LifeStyle Assistant™ (I.L.S.A.) is an agent-based monitoring and support system to help elderly people to live longer in their homes by reducing caregiver burden. I.L.S.A. is a multiagent system that incorporates a unified sensing model, situation assessments, response planning, real-time responses and machine learning. This paper describes the six-month study of the system we fielded in elder's homes and the major we lessons learned about deployment.

1 Introduction

Historically, 43% of Americans over the age of 65 will enter a nursing home for at least one year. In spite of the financial and emotional strain placed on the family, a nursing home is often the only care option available when a loved one can no longer live safely alone.

We have been developing an automated monitoring and caregiving system called *Independent LifeStyle Assistant™* (I.L.S.A.) [4; 5; 6]. Researchers and manufacturers are developing a host of home automation devices that will be available in the near future. I.L.S.A.'s concept is to integrate these individual devices, and augment them with reasoning capabilities to create an intelligent, coherent, useful assistant that helps people enjoy a prolonged, independent lifestyle.

From January to July 2003, we field tested I.L.S.A. in the homes of eleven elderly adults. The I.L.S.A. field test was designed to complete an end-to-end proof-of-concept. It included continuous data collection and transmission via security sensors installed in the home, data analysis, information synthesis, and information delivery to I.L.S.A. clients and their caregivers. The test concentrated on monitoring two of the most significant Activities of Daily Life: medication and mobility. All ADL-based monitoring was performed by family caregivers.

This paper describes the system we built, outlines the field study, and then describes the major lessons we learned relating to configuring the system and interacting with clients:

- Configuring the system
- Designing and deploying usable interfaces
- Client selection and testing

We also learned numerous lessons relating to development and deployment of an artificial intelligence system; more details can be found in Haigh *et al* [3; 4].

2 System Description

The main goal of the field test was to demonstrate the complete cycle of I.L.S.A. interactions: from sensors to data transmission to reasoning to alerts and home control. The field study was also designed to determine the effectiveness of this type of product in maintaining or improving the independence of the elderly subjects. The system we field tested had the following significant features:

- Passive Monitoring: basic mobility, occupancy, medication compliance, sleeping patterns.
- Cognitive Support: reminders, date/time of day.
- Alerts and Notifications: auto contacting caregivers (by telephone).
- Reports: summary reports of client behavior.
- Remote access to information (allowing users to monitor or interact with the system).
- Control: modes (on/off).

Other capabilities and features were tested in the lab.

2.1 Architecture

Requirements for I.L.S.A. included that it had to be rapidly deployable, easy to configure, and easy to update. We therefore decided to use an agent-oriented approach [5]. We selected JADE as our environment [1]. The agents in the system included device controllers, domain agents, response planners, and system management. Haigh *et al.* [4] describes the fielded system in more detail.

The hardware employed in the I.L.S.A. field test consisted of readily available Honeywell home automation and control products. The Honeywell Home Controller served as the backbone for communicating sensor events out of the home. I .L.S.A. was designed to operate on real-time data from the home, so reliable broadband access was a crucial linchpin of this architecture.

2.2 Field Study Environments

Beginning January 2003, we installed I.L.S.A. into the homes of eleven elders and collected data through July 2003. We limited the number of sensors in the elders' homes for

Figure 1: A sample webpage from the elder user interface.

reasons of cost and concerns about privacy—for example, it would have been difficult to find appropriate test subjects who would accept a system with a toilet flush sensor. Each test home had from four to seven sensors, including one medication caddy and several motion detectors. Two installations had a contact switch and pressure mat at the exit door.

2.3 User Interface

Elderly clients were equipped with Honeywell Web Pads™ with wireless access to the Internet over a broadband connection. Through the Web interface, the elders could display reminders, medication schedules & status, mobility summary, on/off controls and information about their caregivers. Figure 1 shows a sample web page for the elderly client. I.L.S.A. could also deliver reminders to the elder by telephone.

Caregivers could access I.L.S.A. data about their client/family member with their normal ISP Web connection. The caregiver Web interface allowed the caregiver to view and acknowledge alerts, view general ADL status (including historical trends for medication and mobility, view and edit prescription and medication schedule, and set up scheduled reminders and personalized activity alerts.

Alerts and reminders could be delivered by telephone. In addition, a dial-in telephone interface allowed caregivers to get abbreviated status reports and record and schedule reminders for the elder.

3 Lessons: Configuration and Customization

Configuring, installing, and customizing I.L.S.A. for each client consisted of (1) installing or delivering the necessary Internet service, sensors, controls, and Web Pads to the clients' homes and (2) entering client-specific data into centralized databases. Over the course of configuring 15 homes, we learned a good deal about our specific design and some lessons that are applicable to any similar, multi-client system.

- Hardware installation is never easy. Each home was a new test of the sensors, the communications, and the installer's nerves.
- Request only the client data you expect to use.
- Base configuration on objective data wherever possible.
- When subjective information is required, make sure that the instructions coincide with the implementation and, if possible, re-configure when objective data is available.

In this section, we discuss issues related to making I.L.S.A. available to individual clients.

3.1 Lesson #1: Hardware Configuration

Even though the data collection architecture was tested in engineer's homes early in the program, deployment to client sites proved problematic. Small changes in network configurations, differences in broadband service providers, wireless networking issues and numerous other issues, including faulty or inadequate hardware components conspired to make each installation a unique experience. Even within the same community living facility, using the same broadband provider, small differences in wireless configurations caused significant consternation in one or two units. Correct configuration was never straightforward.

In part, these issues were related to the use of off-the-shelf components that were not originally designed for this usage scenario. The evolution of Internet security practices, messaging protocols, and everyday service reliability issues also came into play. Finally, the complexity of this system, the novel use of the components, and the limited (and distributed sites) made it impossible to build a sufficient installation experience base.

Though the architecture choices were appropriate for our purposes, the following issues should be accounted for in a product architecture:

- Broadband service availability, reliability and troubleshooting.
- Installation standardization.
- Hardware simplification/standardization.
- Tools for testing/verification of installation.
- In-depth training for installers.

3.2 Lesson #2: Collecting Configuration Information

Deploying I.L.S.A. in a home requires information about clients and caregivers, including contact information, capabilities, medications, and living habits. We asked caregivers to complete forms, and had a field worker (in our case, researchers or nurses) interview the client.

The form describing medication regime requested medication names, reason for using, schedules for taking, dosage type and size, and prescribing physician. The format worked well and translated easily to the data base and interface design and usage. It succeeded because the information was wholly objective.

On the other hand, the form for obtaining mobility data was both subjective and poorly matched to our data collection design. Here we asked clients to assess how active they were during each day-period (morning, afternoon, evening,

night) on a 7-point scale. First, the 7-point scale was misinterpreted, and users are speaking relative to what they *think* they should be doing—so selecting a 5 or 6 for night time activity means something different from the same selection during waking hours.

Second, I.L.S.A. expected the degree of activity to be measured over the entire 6 hour day-period. These subjective measures meant that the mobility ranges we configured seldom agreed with the clients' actual mobility. For the most part we found that they overstated their activity levels, so the mobility comparisons were generally low.

We see two solutions to these problems. The first is to design a questionnaire that is completely objective and asks for *exactly* the right information. However, a significant risk for this kind of monitoring system is that clients and caregivers may simply be *unable* to provide objective information about activity and living patterns, even if the questions are completely objective. Therefore, the second solution is to utilize Machine Learning techniques to automatically configure the information based on collected data [3].

We have shown that machine learning techniques can be successfully applied to reduce the risk of inaccurate configuration based on interview alone. While systems that use this approach will be far more reliable in the field, they will require a "getting to know you" probationary period during which special handling of notifications should be expected.

3.3 Lesson #3: Databases

The main I.L.S.A. database holds the majority of the contact and individual system identification data for all clients. Individual databases for each client accept agent analysis and notification data and hold the medication schedule, expected activity ranges, and contact telephone numbers.

The design decision to use separate client databases was made early in the program when a distributed deployment was being considered (e.g. a database in the client's home). When that direction was abandoned to reduce overall complexity, the databases remained disconnected. Further complicated by our selection of a feature-limited, Java-based database, our databases were still unnecessarily complex and inefficient.

The database schema evolved from earlier iterations and test systems. A database founded on the same precepts as the ontology [4] would have supported richer and more flexible interactions between all the agents and users of the system.

4 Lessons: User Interface

The I.L.S.A. field test system targeted two specific audiences, elderly clients and their family caregivers, using two delivery channels, web and telephone. A basic description of the interfaces we delivered is in Section 2.3. We learned several other lessons about interface design and use:

- Interfaces should be simplified. While this is a universal truth, with I.L.S.A. we found new twists for diverse audiences.
- Telephone interfaces are even harder to design than we expected.
- Elder clients were not as technology averse as anticipated, and desire an interactive system.
- Information architecture, agent architecture, and web design should be more closely integrated.
- Speech recognition and generation technology is not mature enough to handle interactions with the elderly.

Early in the program, we identified several significant interaction design risks, including intrusiveness, and incomprehensible interactions. Our best efforts to design highly usable and friendly interactions for I.L.S.A. did not completely avoid these risks as noted in the following sections.

4.1 Lesson #1: Web Page Design

Both clients and caregivers surprised us with their reactions to these interfaces: clients wanted and could use *a more complex* web interface than we expected, while caregivers were *less interested* in the data than we anticipated.

Client Web interface: Client interactions with the website were entirely information-pull actions. They had no explicit requirement to use the web interface, but could view it as often as they wished, or not at all. We tracked navigation through the web pages but none of the pages included interactive elements requiring data input or acknowledgement.

Clients were generally very accepting of the interface. Most viewed it daily, and were interested in the reports displayed there. 60% of clients reported feeling comfortable with the interface. They appeared to understand the data that was presented, and reported a desire to have a more interactive interface.

A risk that we identified early in the program and attempted to avoid was the use of insufficient or inappropriate communication devices. The Honeywell Web Pad™ device presented a problem for many of the elders. Even those who had prior computer experience found it easy to get lost on this non-dedicated, highly functional, wireless computer. Interaction devices deployed to elderly clients should present a simplified and dedicated interface.

Most current monitoring systems for the elderly provide personal emergency services only, and therefore generally have no interaction device other than a dedicated phone with two-way speaker capability. At the time I.L.S.A. was conceived, no other systems were attempting a high level of communication with an elderly client using a computer interface. Our experiments with I.L.S.A. show that this communication and additional interaction have the potential to be beneficial to clients, making them more active in the management of their own health, and providing additional cognitive stimuli.

Caregiver Web interface: Figure 3 shows the caregiver accesses to the website. Caregivers rarely looked past the initial status overview. They almost never looked for the trend graphs of ADL history, and to our surprise showed a general disinterest in reminders. In particular, caregivers rarely set up reminders for clients, and did not use them as designed. We believe several factors contributed to this inattention within our test group:

- No immediate health crisis (they were not taking care of

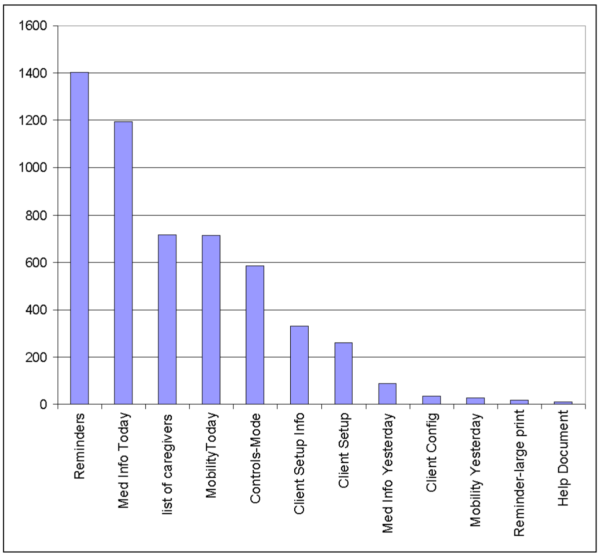

Figure 2: Web page usage on the Client User Interface.

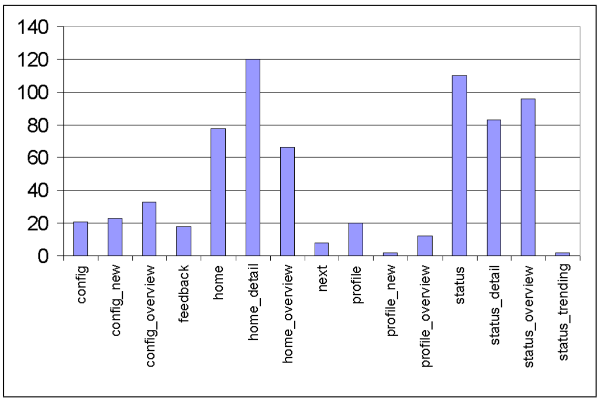

Figure 3: Web page usage on the Caregiver User Interface.

their parent on a daily basis)

- Too busy
- Ineffective web design "hid" the features from plain view

In general, family caregivers want succinct reports, including details about today, charted history of important indicators, and links to further details. Our design gave them too little at a time.

Most systems on the market today provide little or no reporting to family caregivers. Some caregivers did use I.L.S.A. to improve their peace-of-mind by accessing up-to-the-minute reports on their client's wellbeing. While I.L.S.A.'s caregiver interface proved to be off-the-mark in terms of presentation, making more information available to family members could make even simple personal emergency systems more valuable as a long-term care tool.

4.2 Lesson #2: Web Architecture

We made significant architecture choices before the interface design was complete. Most notably, we decided to completely separate the web interface from the agent system because of security concerns and independent development.

However, the partitioning required to keep web servers secure works against inter-process communication with processes running in the web environment. One operational impact of this design was a significant latency between changes in client configurations (via the web) and adoption of new settings by system agents. Both the web interfaces and agent system had to regularly poll the database for changes. More than simply inefficient, this structure occasionally caused scheduling conflicts within the agent system. It raised the potential for confusion, since the user interface could display information that was inconsistent with active agent parameters.

While possible, building a direct link between the agent system and the web interfaces was not a priority in reaching our project goals, though it is clearly a priority in a production system. A more integrated system would also have kept system developers more in tune with each other's progress as the system evolved.

In addition, the caregiver web site evolved from a design to support health professionals with multiple clients. The design had a complex set of disjoint client and system databases. When it was decided to test the system with only family caregivers, the databases and caregiver interface could have been simplified.

4.3 Lesson #3: Telephone Interface

The I.L.S.A. telephone interfaces consisted of message delivery—reminders to clients; alerts about possible client problems to caregivers—and a dial-in enquiry system for caregivers. The dial-in interface was an alternative to the caregiver web site.

Dial-in status enquiries: Caregivers were even less likely to use the dial-in I.L.S.A. interface than they were the web site. Only one caregiver, who did not have access to the web at work, used it regularly.

Reminder and alert delivery: Despite much literature indicating the effectiveness of telephone interfaces [2; 8], I.L.S.A. test clients universally disliked the telephone message delivery. We found that:

- Messages were perceived as computer-generated, even though a pleasant pre-recorded voice was used.
- We asked for acknowledgement that we reached the correct person, e.g. "Press one if you are Lois." The cognitive and visual load required to complete this interaction was too high in many cases. (The message was not delivered if the call was not authenticated.)
- The calls were intrusive, sometimes waking clients if they were not following their typical schedule.

Avoidance of these calls was cited as one reason for clients' compliance with their medication schedule. Unfortunately, call avoidance also resulted in attempts to fool I.L.S.A.; for example, one elder would open the medication caddy "on time," but not actually take the medication until later.

While the telephone is widely agreed to be a device that most people are comfortable using, the comfort applies only

to conversations with real people. Recorded voices, even familiar voices, can be confusing. Responding to the system is stressful for some elders, and impossible for others. Still others find it difficult to talk to a real person they can't see—even "normal" telephone use with familiar people may be problematic.

These issues also tended to hold true with the caregivers in the study. While caregivers were more capable of the cognitive challenge, calls initiated by a machine were not desirable, as indicated by caregivers choosing to ignore the request for authentication, caregivers ignoring the automated messages, and caregivers panicking. Caregivers found it more acceptable to call in to an automated system at their own convenience.

4.4 Lesson #4: Speech Recognition and Delivery

At the beginning of the program, we felt strongly that a speech interface was a mandatory component for this kind of system. After analyzing the problem domain in more detail, exploring the technology, and doing some pilot studies, we decided to remove the capability completely. Our decision was based on three factors:

1. It is difficult to understand an elder's voice. Not only is it difficult to locate enough microphones to get a high quality signal, but elders also have less "rich" voice streams. An elder's voice or speech patterns can change dramatically with medical issues such as a stroke, and even during the course of a day due to fatigue. Removal of dentures or simple distress will significantly reduce the ability to recognize speech during actual emergency situations.
2. Interactive speech interfaces can confuse an elder when they hear a "disembodied voice"; elders cannot cope when the system misunderstands; and elders cannot handle the delayed response time caused by (possibly remote) processing. Familiarity with the voice, or the message, does not necessarily mitigate this problem.
3. The technology is not yet ready to handle the complexity of interactions with elders. This third factor was the overriding concern: the system must not only generate dynamic syntactic structures so the elder doesn't hate the interface, but it must also understand the situation to a greater degree of accuracy than we can provide (including when to "coax" the elder). Take for example, the conversation scenario of Table 1. This conversation shows a deep understanding of the situation and its severity, in that it's not an immediate emergency, but a situation of concern. The system recognizes that Lois is reluctant to be a burden and needs to be coaxed to accept help.

System: *Lois, it looks like you've fallen. Are you OK?*
Lois: *Yes, I'm fine.*
System: *But you haven't moved in 5 minutes.*
Lois: *I'm OK. I'm just winded, that's all.*
System: *Are you sure you don't want me to call for help?*
Lois: *Yes, I'm sure.*
System: *Maybe you'd like me to call your daughter.*
Lois: *But I don't want to be a bother.*
System: *I'm sure she wouldn't mind.*
Lois: *OK, call her. But don't tell her I've fallen.*

Table 1: A sample conversation between an intelligent monitoring system and an elder.

Koester [7] provides additional evidence that speech interaction is unlikely to be effective in this domain. Among other issues, they point out that there is a significant "cognitive cost" to use speech recognition systems: the user must notice and correct recognition errors, learn how to speak to maximize recognition accuracy, and learn a (possibly large) set of commands to control the system. Moreover, more cognitive resources are required for speaking than for physical activity. The elders most suited to use an I.L.S.A.-like system are unlikely to be capable of meeting this challenge.

5 Lessons: Client Selection and Testing

In selecting I.L.S.A. clients and obtaining feedback and test results, we learned a great deal about selecting appropriate participants, and confirmed the most effective method for achieving a high response rate to surveys.

The risks we identified early in the program proved to be very real. Formal evaluation is a very expensive process; resource pressures reduced our emphasis in this area. We also had difficulty getting as many test subjects as we were hoping for, although once in the program, client retention was not an issue.

To be eligible for the study, a resident was required to be living alone, and competent in all activities of daily living (ADL), such as bathing dressing, grooming, eating, transferring, and toileting. People could be dependent in one instrumental ADL (e.g., shopping, managing money). Each person also had to identify a family member (caregiver) with access to a computer who agreed to participate in the study. Because of the sensitivity of the motion sensors, eligible persons could have only small pets.

In Minnesota, personnel at Presbyterian Homes invited residents to learning sessions about the I.L.S.A. study. Study investigators visited each facility and made presentations for all interested persons. At two facilities, we obtained a list of 23 potential clients. Dr. Krichbaum phoned interested residents and then visited each to explain the study and to obtain consent. Of the initial 23, 11 (47.8%) agreed to participate. By the time the study began, seven clients (30.4%) remained. Reasons for attrition included:

- time commitment
- some potential clients spent at least part of the year away from the state
- objections of family members

We did no statistical tests to determine if those who stayed in the study were significantly different from those who did not. The age range, however, was certainly comparable.

Our Florida clients had to meet the same conditions, and were recruited by the University of Florida's Department of Occupational Therapy. Our process yielded four clients.

5.1 Lesson #1: Selecting Participants

Our approach for selecting participants was designed to attract elders who were not too frail – very frail elders could

be at risk from a prototype system. As a result, our approach netted clients who were *interested* in participating in a test, but not necessarily those that were most in *need* of the technology. As a result, more than 60% reported that I.L.S.A. was not contributing much to their independence. Furthermore, even fewer of their caregivers were appropriate. Most of them were local and felt confident of their parent's health and safety in the relatively secure environment of the living facility. None of the caregivers were uncomfortable about their client's safety, even prior to installing I.L.S.A. Consequently, the feedback we received from participating caregivers was very thin.

Clearly, to learn more about the acceptance of these systems by family or professional caregivers, and appropriately frail elders, test subject selection needs to center on caregivers with the most need, rather than clients with the most interest.

5.2 Lesson #2: Obtaining Feedback

Each week from February 1 through July 31, 2003, an investigator phoned each client. The clients were asked to comment on the usability, advantages and disadvantages/issues of using I.L.S.A. Given this collection method, feedback was consistent and complete. Similar questions were asked of family caregivers who could complete questionnaires on the web or mail them in. Three or four caregivers were very engaged and returned several surveys; most were not very engaged in the process. While we could have badgered these caregivers for results, the answers would have been predictable—those caregivers did not feel a need for I.L.S.A. in the first place.

6 Conclusion

The lessons we learned relating to the software plateform and the artificial intelligence approach are described in more detail elsewhere [3]. If we continue research on the Independent LifeStyle Assistant™, we will eliminate the agent-based approach, while keeping the other AI technologies. The largest technical barriers we perceive are:

- further development, testing and verification of intelligent automation within this domain;
- development of a more effective medication management system, including 360-degree pharmaceutical services;
- development of effective and comfortable methods of communication between the system and the elderly clients.

We view the I.L.S.A. program as a success because of the following significant achievements:

- We successfully prototyped a passive monitoring system for elders in their own homes.
- We have a much better understanding of what constitutes an *acceptable* monitoring system for elders and, in particular, disproved some of the assumptions made about "technophobic" elders. Through our Knowledge Acquisition effort, we learned what factors affect elders' independence and identified technology opportunities. We improved the understanding of factors that impede the delivery and acceptance of assistive technologies, and also improved our ability to overcome these factors.
- We validated the importance of artificial intelligence technologies to support a broad customer base in widely varied and unstructured environments. Notably, we have validated the importance of machine learning as a technique to mitigate expensive installations and ongoing adaptation [3].

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