Honeywell

Independent LifeStyle Assistant™ (I.L.S.A.):

AI Lessons Learned

A NIST ATP Program

Karen Zita Haigh
Karen.haigh@honeywell.com

C02117-01

In a Nutshell

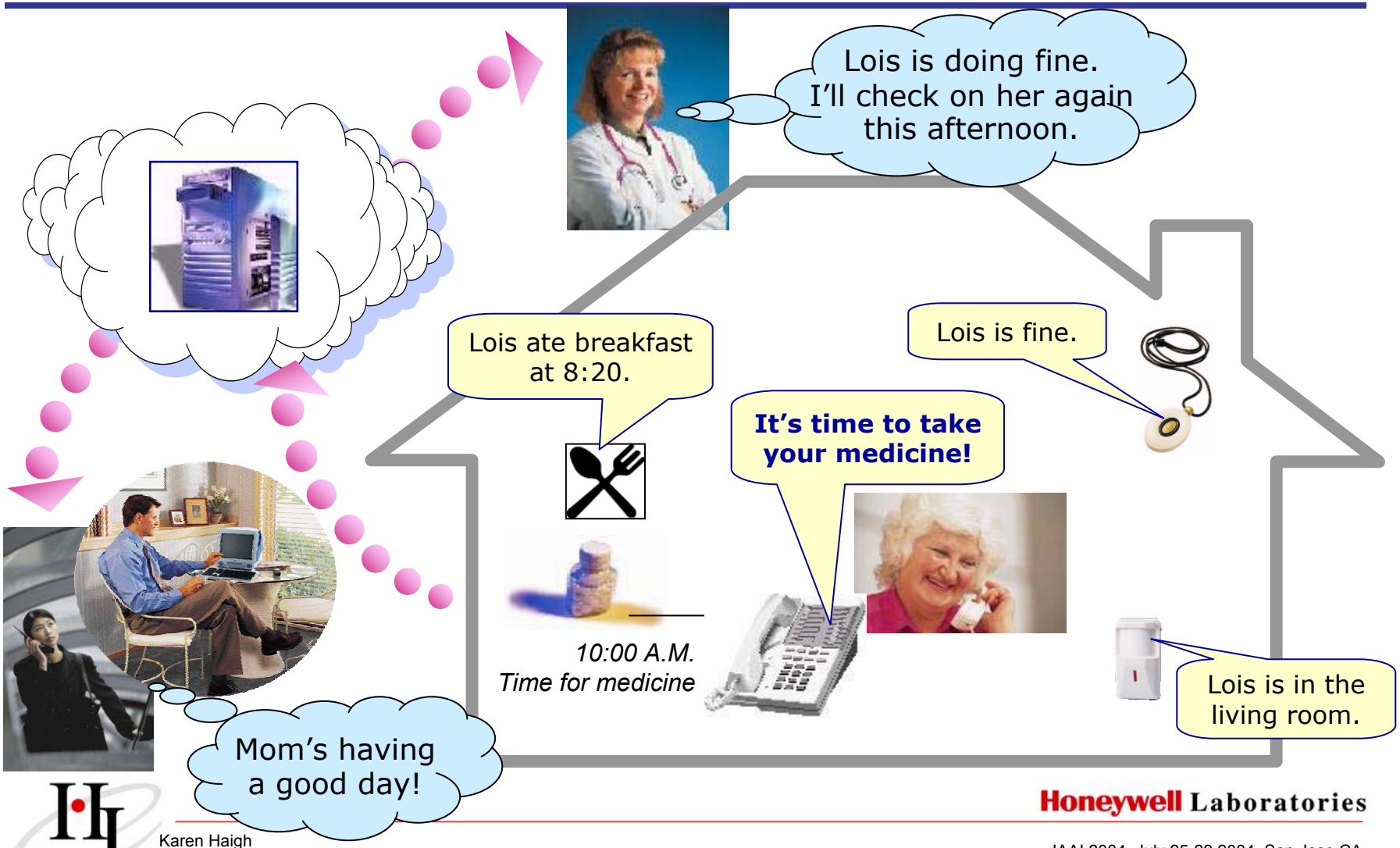
Program Objective

Develop an intelligent home automation system with situation awareness and decision-making capability based on integration of diverse sensors, devices, and appliances to support caregivers and enable elderly users to live independently at home.

Expected Benefits:

- Support elder independent living
- Provide peace of mind to caregivers
- Support efficient quality care for caregiving organizations
- Cost savings for government and industry
- Market growth for in-home product producers

The Vision


Lois is doing fine.
I'll check on her again
this afternoon.
Lois ate breakfast
at 8:20.
Lois is fine.
It's time to take
your medicine!
10:00 A.M.
Time for medicine
Lois is in the
living room.
Mom's having
a good day!

Factors Precipitating Institutionalization

Literature reviews, interviews with adult children caregivers, and discussions with geriatric experts identified the most significant factors that pose a threat to the independence of elders.

- **Mobility**
- **Medication Management**
- **Eating**
- **Toileting**
- **Isolation**
- **Medical Monitoring**
- **Cognitive Decline**
- **Safety**
- **Caregiver Burnout**

Existing monitoring systems often focus on a single function – little or no integration

Feature Set

Monitoring Functions
- Mobility (general activity level)
- Medication caddy monitoring

Response Functions
- Alerts
- Notifications
- Activity Reports

Service Features
- Reminders
- Internet & phone access

Usability Features
- Password-free elder interactions
- Operational modes (on/off)

User Interfaces
- Elder: Phone, Webpad ™
- Caregiver: Web, phone

Design Philosophies:

Passive
- Allow elders to follow regular routines without imposing new ones
- No worn devices

Minimal intrusions
- Only reminders and alerts
- No requirement to use web interface for proper system behaviour

I.L.S.A. Field Study System

Client Interface
Honeywell Webpad™
anywhere in client's home

Caregiver Browser
From any internet connection

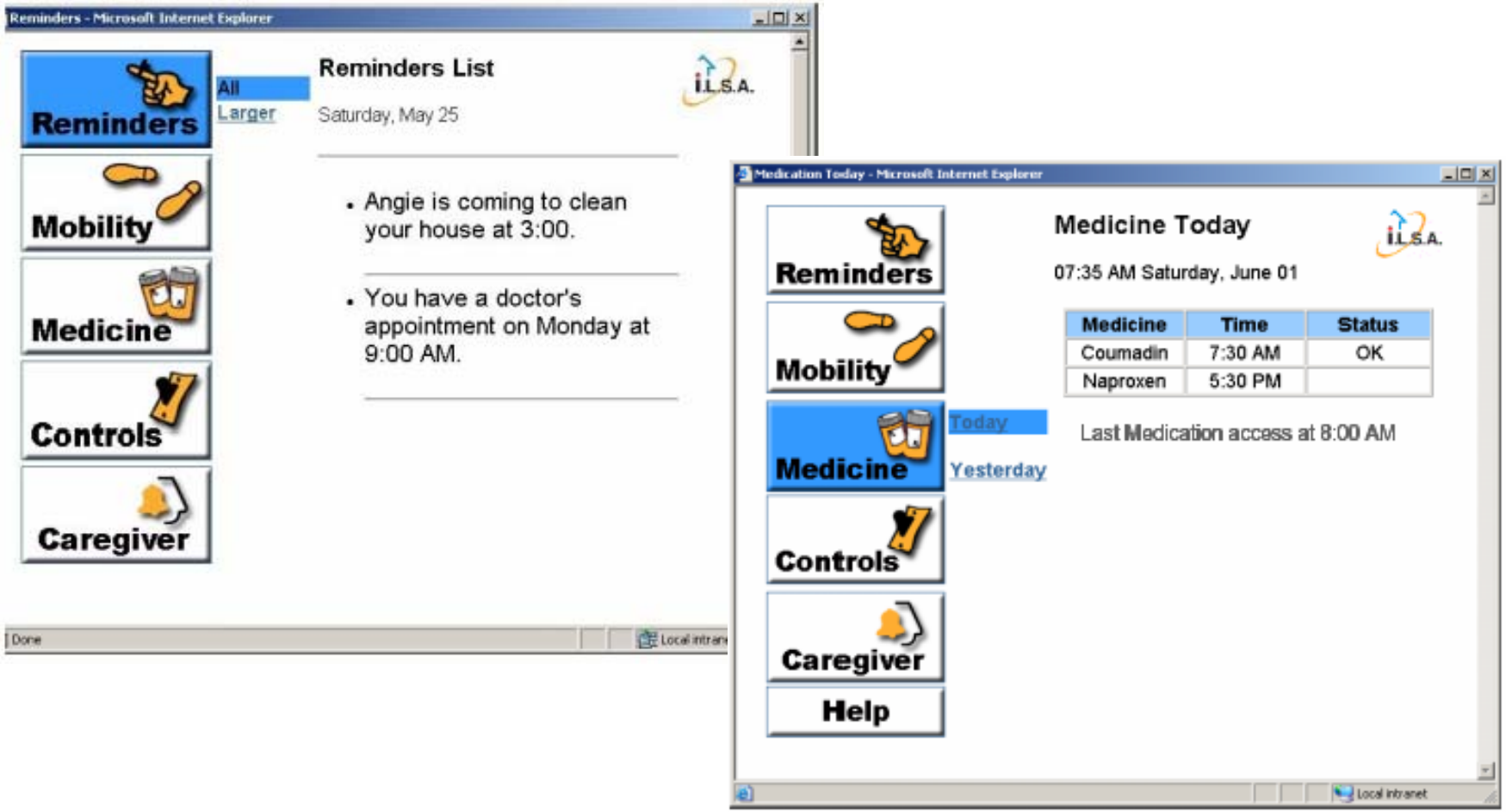
Wireless Sensors
monitor general or
specific activities

Hidden **control and communication** components

Broadband
internet

I.L.S.A. Server
Modular agent-based System

I.L.S.A. Client Interface



Software Architecture Requirements

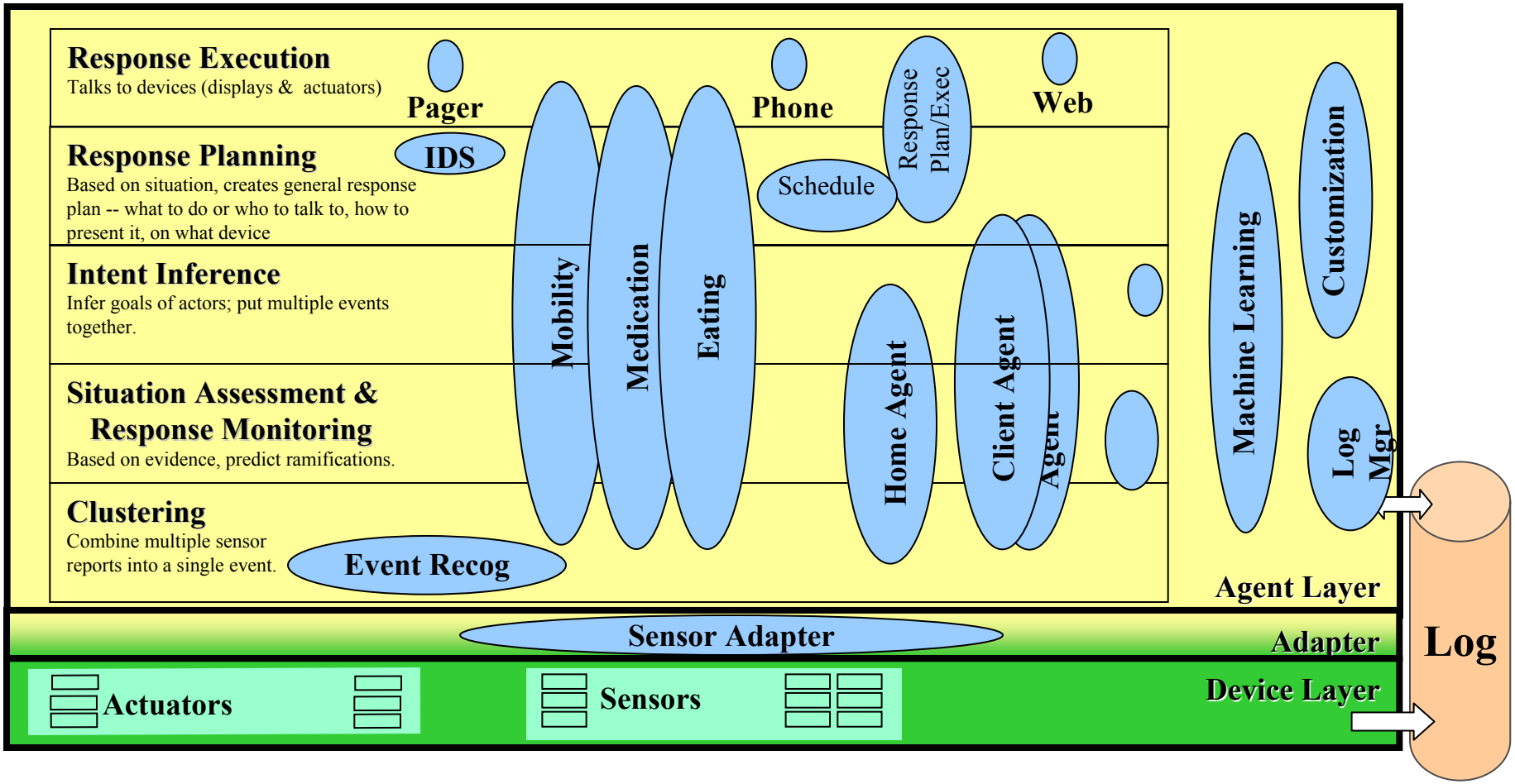
Each ILSA client and home will be very different and have specialized needs, so the system must be:

- rapidly deployable,
- easily configurable,
- highly modular, and
- adaptive to the environment.

Modularity is critical both to functionality as well as expandability for a number of reasons:

- Integrate 3rd party functional units
- Flexibility of sensor and actuator suites
- Expansion of ILSA capabilities over time

Agent Architecture



I.L.S.A. Agents

Agents group functionality, e.g.

- Mobility monitor
- Medication monitor
- Client interaction module
- Device controllers

Agents group technical capability, e.g.

- Machine Learning
- Task tracking
- Response Planning

Lessons - Agents: Multi-person development

Expectation: independent agents could be assigned to independent developers

Result: not true – considerable development overhead

- Agents that communicate with each other must be developed together
  - » Communication protocols
  - » Recovery from failures
  - » Ontology development
  - » Logical protocols

Lessons - Agents: Testing & Debugging

Expectation: independent agents could be independently tested

Result: not true

- Free communication means *every* possible interaction needs to be tested
  - » In a monolithic system, testing can focus on the single point of change
- Errors can propagate along communication channels, and therefore are hard to isolate
- No enforcement of logical protocols – same bug may appear in multiple agents

Lessons - Agents: Scalability

Expectation: distributed architecture would support scalability

Result: not true

- Bottleneck agents
  - » e.g. database, communication with elder
- Scoping is very difficult because there is no mechanism to enforce logical protocols
- New capability (agent) meant new interfaces for existing agents
  - » Compounded by multi-person develpment
  - » Adds to testing effort

Lessons - Agents: Robustness & Reliability

Expectation: distributed processing would mean no single point of failure

Result: not true

- Certain capabilities need to be centralized
  - » e.g. communication with elder
  - » Redundancy is not a solution
- There is no general solution to persistence over restarts
  - » Each agent must have its own solution

Lessons - Agents: Summary

Agent technology is not ready for this domain. It needs much more support for

- Debugging & Testing
- Reliability
- Enforcing logical protocols

The more capabilities need to be centralized, the less likely agent technology will be appropriate.

Domain Ontology

A common vocabulary that lets agents communicate with precision about the world

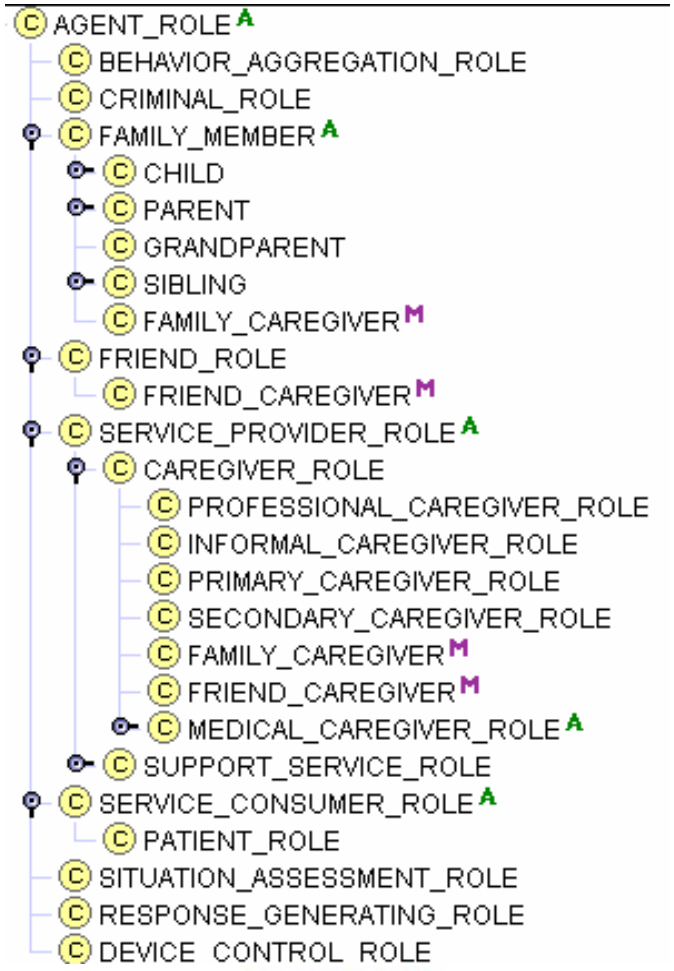
It provides standard interpretations for words

- that might otherwise be dangerously ambiguous

It structures the domain knowledge in ways that allow it to be analyzed,

- making assumptions more explicit

Being presented to CAST / HL7



Ontology: Lessons

One ontology for multiple purposes means no duplicated concepts, but is harder to learn

Don’t waste effort defining terms not explicitly dictated by the application

Be conscious of cross-cultural compatibility

Artificial Intelligence

Task Tracking

Response Planning & Coordination

Machine Learning

Short answer: AI is very useful for this domain, especially as tasks grow in complexity

AI: Task Tracking

Recognize what the client is doing

System must handle:

- Multiple hypotheses
  - » One sensor sequence may mean two different things
  - » Be aware of how confident it is in the recognized sequence (e.g. competing possibilities, or noisy sensors),
- Unobservable actions
  - » e.g. when a sensor failed
- Abandoned plans & Failed actions
  - » Recognize what the person was TRYING to do, even if they didn't actually succeed or have not yet completed the task
- Partially ordered plans
- Actions used for multiple effects

Barriers:

- Richness of sensor suites
- Libraries of activities

AI: Response Planning

Generate interactions with the client/CG

System must coordinate responses

- (w*ho, what, where, when, how)*
- Timely
- Prioritize messages
- Multiplex messages
- Without overloading the resources (device or human)

Challenges

- Accurate use of context
  - » Never cry wolf

AI: Machine Learning

Learn models of the actors and environment to automatically improve the performance of the system:

- what is normal / unusual
  - » Patterned behaviours, Schedules, Unexpected activities
- what is the most effective technique to use
- understand sensor reliability

For configuration, adapting to the changing elder, and capturing preferences of users

Barriers:

- Evaluation (no ground truth)
- Automatic incorporation of learned models

Reactions to I.L.S.A.

Clients were engaged and interested

- Most clients checked their page at least once a day, even in the last month of testing

Clients did not appear to become dependent on reminders

- In fact, avoiding telephone reminders helped them exercise their memory

Clients liked the minimal disruption to their normal routine.

Summary

AI is perfect for this domain

- But don't forget the other problems you'll encounter when you field a system

Agent architectures need more support tools before they will make it out of the lab

- Particularly since AI researchers are not software engineers

http://www.htc.honeywell.com/projects/ilsa

(Deployment lessons – see AAAI-04 workshop "Fielding AI Technologies")