Client Unique Identification For ILSA

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Document History

Table 1

Version	Prepared	Description
1	2001-09-06	Initial draft, mostly table of solution technologies.
2	2001-10-02	Added section on available products.
3	2001-10-31	Expanded available products, discussion of face recognition and camera tracking approach.
4	2001-11-05	More detail on requirements; taxonomy of approaches.
6	2001-11-09	Polished some references.
7	2001-11-12	Added more conclusions, abstract, discussion of requirements.

Abstract

ILSA frequently needs to know where the client currently is located in the residence. Technologies exist to do this with varying degrees of accuracy, cost, and intrusiveness. The task is more difficult in multi-person households, but still quite feasible. Commercial systems for tracking individuals inside buildings are available and could work well, although they tend not be economical for single-client home use. A combination of inexpensive sensors and analytic methods could provide fair performance in the short term. High accuracy systems based on camera and acoustic technology are on the horizon.

Requirements

The requirements are driven by use cases, notably "*103.1 location tracking use case.doc*"[1], however a certain amount of extrapolation was required since the use cases are moderately ambiguous regarding required precision. Three themes emerge. ILSA will apply location information to determine how best to communicate with the client, e.g. determining what interaction devices are within range. ILSA may also use location information to drive automated assistance such as path lighting, door opening etc. Finally, ILSA may use location information to infer activities that are to be monitored, e.g. kitchen and bathroom use, time spent in bed.

Conditions

1. The assumed scope is a single client private home, possibly multiple floors.
2. There may be up to two *other* persons present in the home simultaneously.
3. There may be a large *dog* present in the home with (or without) the client.

Basic Questions

There are two basic questions that the location system is called to answer:
1. Where in the residence the client is located at the current time (indicate if client is not present)?
2. Did the client perform a certain operation?
- "Who entered the front door at 10:20:11?"
- "Who opened the refrigerator door at 09:00:44?"
- "Who turned on the stove at 18:16:10?"
- "Who flushed the toilet at 04:00:00?"

We will see that in some cases these questions can be disentangled.

[1] Revision 0.1, R. Whillock, 7-May-2001

Precision

Precision of the response is assumed to vary depending on the level of instrumentation, client cooperation, and environmental factors. We distinguish three separate levels of precision, with the highest being the most desirable

- **Level-1** indicate whether the client is in the home our outside of it.
- **Level-2** indicate which room (or area) of the home the client is in.
- **Level-3** provide client position to within +/-1 meter in a house-centered coordinate system.

Different scenarios demand different levels of precision. It may be acceptable to assure the highest precision only in certain areas, e.g. the kitchen, while lower precision tolerable elsewhere.

Reliability

Provide a confidence level for all answers, including alternative answers. E.g.
Pr{kitchen/NW} = 0.85, Pr{front-hall}=0.10, Pr{other}=0.05

Latency

Provide a reading that is no more than **5 seconds** late. This figure is motivated by the approximate time required to exit a room. The nominal situation to avoid is an annunciation is delivered to the wrong room due to latency.

Ancillary Information

Provide an indication of whether the client is standing or prone. [Desirable]
Provide an identification or position information for non-client persons, pets. [Desirable]

Customer Acceptance

The system should be as unobtrusive as possible. The client should not be asked to wear something uncomfortable. The client should not be given the feeling of being under constant surveillance. These are unfortunately highly subjective questions. Acceptance may be improved when the explicit benefits of the system are clearly explained.

Cost

The total installed cost for the location technology shall be less than $K. The threshold for K is unknown, and a divisional/insurance question. Figures in the low hundreds of dollars have been mentioned.

Tracking Taxonomy

There are many ways to breakdown the available techniques for tracking individuals (see, for example, the article in *Computer* August 2001). The summary here differs from others in two respects. First, our primary focus is on the indoor environment. Thus we reject out of hand a number of techniques designed for outdoor use, notably GPS satellite based systems. Second, we are particularly sensitive to the degree to which clients must cooperate in the tracking task. The latter consideration leads to a taxonomy of tracking approaches shown in Tables 1-3. We call technologies that do not make any demands on the client to wear any sort of apparatus or perform in particular ways *Completely Passive*. Other techniques expect the client to reliably wear a transponder of some sort, press buttons or present badges; these we designate as *Active*. A few techniques fall in between Active and Completely Passive, and these we term *Mostly Passive*.

Table-1	***Completely Passive Technology***
IR1	Passive infrared camera looks for warm blobs that match the size and shape of the client (which hopefully is distinct from that of the caregiver).
VR1	Voice recognition, passive. Learn the unique timbre of client's voice. When voices are heard,

Table-1	***Completely Passive Technology***
	use microphones arrayed throughout the house to estimate position.
FR1	Face recognition by visual light camera. This could work in certain spaces, e.g. inside refrigerator, behind bathroom 2-way mirror.
VC	Video camera or cameras offer tracking of individuals within rooms and hallways (DETER-like technology). Use track statistics, e.g. speed, to identify individuals.
MO1	Modified motion sensor indicates not only presence of movement in a given room or part of a room, but level of activity. Attempt to learn differential activity levels for client and other residents.
MA1	Mass sensor, "smart floor". Pressure pads measure the weight of the object on them. We track client and caregiver weights and/or gait accurately and use this to determine whether it was the client on the pad.
CO2	Measure carbon dioxide levels to infer the respiration going on in a room. This might be able to let us estimate the number of (live) individuals in the room.

Table-2	***Active Technology***
TX1	Client wears a radio transmitter/transponder. Antennae in the house allow triangulation of position to within 3-meters.
TX2	Client wears a modulated infrared transponder. IR sensors in various rooms allow client ID to a particular room.
TX3	Client wears an ultrasonic transponder. Acoustic sensors in each room allow resolution of position to within 0.03 meters.
RX1	Client wears an ultrasonic receiver; uses triangulation from multiple ultrasonic sources to calculate position. Uses RF link to transmit back to ILSA.
ID1	Radio transponder(s) at doorway(s) and other special locations given identifiers for all authorized individuals.
VR2	Voice recognition, active. Active location query via voice. "Lois, are you in the bathroom?" "Yes, don't bother me!" Maybe combine with VR1 to validate speaker. A variant of this would be voice activated locks or controls on devices so that the client has an incentive to speak. Lois-to-Toilet: "Flush"
BC1	Printed badge with optical barcode or other unique pattern is scanned by laser. This would work best in certain constrained spaces.
FP1	Fingerprint reader is used to control key devices. E.g. to turn on the stove, Lois must press her forefinger on the reader instead of the conventional control.

Table 3	***Mostly Passive Technology***
FL1	Luminescent dye is added to client's shampoo. This compound actively fluoresces when hit with an ultraviolet light pulse. We add UV strobe and camera to track—client is a uniquely bright object in a narrow spectral band.
OD1	Client is given a particular chemical tag, like an odor, but not necessarily detectable to humans. The tag could be put in shampoo, cologne, soap etc. Chemical sensors at key points sample the air for concentration of the tag.
TV1	Learn client's preference for television/entertainment options. Operation of the TV with the client's favorite show adds some evidence that client is present.

Available Products

Table 4 is a sampler of products available for tracking and identification. A number of systems have been pitched explicitly for institutional settings such as hospitals and nursing homes.

Table - 4	***Description***
WhereNet Corp	(TX1) **WhereTags** and WhereTag II's are affixed to tracked items. Each WhereTag periodically transmits its unique serial number over the globally approved, unlicensed 2.4 GHz spectrum radio band. Location Processors are connected to the Location Antennas and, using sophisticated digital signal processing and filtering algorithms, precisely locate tags (and their associated tracked item) to within 3 meters (10 feet). http://www.wherenet.com/homefr.htm
ELPAS	(TX1) Honeywell **Asset Locator** is a repackaging of this technology; we have it in Camden for tracking foreign nationals. Apparent resolution in IR mode is +/-5 ft. RF mode is much poorer, but can monitor places obscured from the IR signal. Receivers are roughly $200. At least one per room would be required. Up to 4 per room would be used to get accurate quadrant determination within the room. Primary market for ELPAS is hospitals. http://www.elpas.com
AXCESS Inc	The **ActiveTag** ™ System uses small, battery powered tags that, when automatically activated at control points throughout a facility, broadcast non-line-of-sight to palm size receivers networked on the existing corporate LAN/WAN, VPN or Internet over IP. Unlike other wireless identification and location systems, ActiveTag's unique dual-frequency operation and advanced capabilities allow tags to be activated and tracked in a variety of useful ways to support multiple business initiatives. Tags awakened by low cost activators transmit not only their unique identification code, but location and status information as well. Tag signals are picked up by network receivers up to 100 feet away, thus allowing a single receiver to collect tag data from a number of activation points. This flexible control point architecture allows users to automatically activate tags at specific locations within the facility to support "proximity" applications, such as access control and perimeter control. These read points could also be grouped into control zones to locate an asset or person within a specific zone, as well as monitor movement between zones. http://www.axcessinc.com/products/rfidoverview.shtml
EXI Wireless	**RoamAlert** "Our RoamAlert line of patient wandering systems offers noise immunity, eliminating false alarms caused by motorized wheelchairs and other electronic devices. Precise and reliable detection zones to ensure better control at busy exit points. Coverage on the inside of an elevator car, not just the lobby. And the smallest and longest lasting patient wrist transponders available in the market." (13 grams) I have the pdf downloaded into F:\Independent-Living\Post-Award\Technical\infastructure team\road_id.pdf http://www.exi.com/exi_main.cfm
Visionetix	**Wireless Transponders** These transmitters are designed for advanced alarm and control systems. Each transmitter has its own 24-bit ID that can be identified by the central station. MCT-101 S, 102 S and 104 S are respectively, 1, 2 and 4-channel, multi- purpose handheld transmitters. MCT-201 S is a miniature pendant transmitter. MCT-201 WP S is the waterproof version of the MCT-201 S transmitter. MCT-201 AT S is the sealed version of the MCT-201 S transmitter, with a lithium battery. It is designed to prevent the unit from being opened. The battery cannot be replaced. MCT-211 S is a waterproof wristband transmitter. **Man-down Device**: MDT-122 S is an emergency transmitter used by security personnel for automatic man-down signaling with the SpiderAlert system. When a guard needs help, he presses both left and right push buttons. A built-in tilt switch activates the transmitter when the holder is knocked down or

Table - 4	***Description***
	when the transmitter is tilted by more than 60° from vertical position. http://www.visonetix.com
Versus Technology	Similar to ELPAS. **VIS** badges emit either infrared (IR) signals or both infrared and radio frequency (RF) signals depending on the badge type. The signals contain the badge's unique identification code. As the badge passes under the sensor, the code is received and transmitted through the system to display the location of the badge on a computer monitor. Wall or ceiling-mounted IR sensors placed throughout a facility receive encoded IR signals from badges. The sensors convert the signals to electrical signals and transmit them to collectors. http://www.versustech.com
Instantel	Instantel's **WatchMate** product line utilizes radio frequency (RF) Technology to monitor Alzheimer's residents in health care facilities who have a tendency to wander away from safe areas. The system eliminates the need for other forms of restraint and allows the resident safer freedom of movement. WatchMate systems sound an alarm to alert staff when a wanderer approaches a protected area. The wanderer wears a small transmitter, approximately the size of a man's sport watch. Monitors are installed at each door, corridor or other protected area to detect the presence of a transmitter and initiate the appropriate response such as locking the door or sounding an alarm. Only the WatchMate system offers remote identification and location using the WatchMate Locator. One or more residents can be located indoors or out. [Some adjustment of the direction finding antenna appears to be involved!] http://www.instantel.com
DigitalPersona	(FP1) "The U.are.U 2000 Fingerprint Sensor is a self-contained device for capturing a fingerprint and communicating the digital image to a host processor via a USB interface. This small sensor is ideal for laptop computers, desktop PCs, and other PC equipment where fingerprint authentication is needed." These tiny devices sell for well under $100 and might be incorporated into some facility we wish to monitor. http://www.digitalpersona.com

Related Research Efforts

Table 5 includes some promising research efforts on tracking that may develop into products.

TABLE 5	***Description***
Randell & Muller U. Bristol, UK	(RX1) This work is very much like "GPS for rooms". The client side is passive—it just listens to the beacons. There are 4 ultrasonic sources and an RF source. They chirp in sequence on a regular basis. The client listens for the chirps and measures time delays, with the RF source being the reference origin. Claimed accuracy is high (< 10cm). Their prototype receiver is fairly bulky—it could not be worn in current form, but there are not any obvious obstacles to miniaturization. In our application, we would need to make the client actively transmit the measured location back to ILSA. This notion is mentioned in the Randell & Muller paper but not implemented. See G.D. Abowd, B. Brumitt, S. A. N. Shafer (Eds.): Ubicomp 2001, LNCS 2201, pp 42-48, 2001. Berlin: Springer Verlag. and http://www.cs.bris.ac.uk/Tools/Reports/Authors/cliff.html
AT&T Research UK	(TX3) The AT&T laboratories Cambridge. "BATs" emitters worn by employees are tracked by microphones in the ceiling of each room (3cm accuracy claimed). Receivers are placed at 1.2m intervals. Each BAT has a unique 48 bit code and a bidirectional 433 MHz radio link. Battery lasts ~1year. Integrated with the LAN in their research facility. See Addlesee, M., Hodges, S., Newman, J., Steggles, P., Ward, A. Implementing a Sentient Computing System *Computer* (IEEE) August 2001, pp 50-56. or http://www.uk.research.att.com/bat See the CNN James Hattori report as a video on http://europe.cnn.com/2001/TECH/ptech/09/17/big.brother.t_t/index.html
Honeywell Labs	(FL1) The idea of using a luminescent dye that is excited in the ultraviolet range is being explored at Honeywell Labs. A commercial shampoo (Silver Fox) used for graying hair, is known to naturally have this property. Hair sprays for costume parties and raves are also available. The attraction of this technique is that would dramatically simplify and improve the reliability of camera-based tracking techniques. This idea has been written up in greater detail in the document H0003362_Lumi-Shampoo.doc.
Georgia Tech	(MS1) The GA Tech Smart Floor uses pressure sensors embedded in special flooring material to sense footsteps. Information may be gleaned from an individual's gait to help identify the client. Currently appears to be a high cost option—the floors need to be refitted in the house. It is however, very inobtrusive. See: Orr & Abowd (2000) The smart floor: a mechanism for natural user identification and tracking. *Proc. 2000 Conf Human Factors in Computing Systems* (CHI 2000). NY: ACM Press.
Microsoft	(VC) "Easy Living". Uses a 3-camera system for triangulation and tracking within a room. There are mixed reports regarding the system's ability to recognize individuals. See: Krumm, J. et al. (2000) Multi-camera multi-person tracking for easy living. Proc 3rd IEEE Intl Workshop Visual Surveillance, pp3-10.

Conclusions

The most reliable and accurate of the techniques available are the Active methods using acoustic or hybrid acoustic technology. These have two chief disadvantages. First, they are expensive, particularly when we consider there is just one client (individual) per installation. These techniques make more sense in a commercial or industrial setting, where the cost may be amortized over many individuals served. The second disadvantage is that the client must wear the transponder for the system to function at all. This could be an obstacle for some fraction of clients who are unwilling or unable to comply reliably. Good estimates of compliance, or notions of incentives for compliance should be considered. We should expect the costs for acoustic systems to decline. This technology should be tracked.

A good combination of high accuracy and modest cost is promised by the passive camera-based systems. Individual cameras of satisfactory are inexpensive when purchased wholesale. A single camera can monitor an entire room or hallway if mounted correctly. The same technique can be used for outdoor monitoring. There are two issues to consider. First, the optics for efficient tracking (high mount, wide angle) is not satisfactory for face recognition. Face recognition requires a fairly constrained head-on shot of the face. Thus to get both unique identification and close tracking, will require multiple cameras or some supplementary technology. The luminescent tagging (FL1) could serve this purpose; this is new technology.

Some of the high-end location technologies could be modified or applied to better fit home use. For example, cost could be reduced by accepting poorer accuracy, perhaps just by installing fewer receivers.

Leveraging With Analytics

Many of these sensors would need to work with analytic software that would compensate for their low resolution or selectivity. For example, switch closure events from simple pressure pads or motion sensors provide point presence indicators but no unique personal identity. Here are some conjectures about inference from some of these less precise sensors.

- If we have been tracking someone from point to point, starting with a plausible point of authentication, e.g. client's bed in the morning, we will be able to escalate our confidence in the association of the client with the switch events based on consideration of travel times, locations of other individuals etc. This becomes more difficult when multiple persons enter a given room. You cannot tell who leaves the room until further data arrives. You may be able to make inferences based on travel time after a blip shows up in another room that was, e.g. too fast to have been the client. Similar lines of inference about trajectories were used in the DETER camera tracking project.
- You may be able to learn client habits and distinguish these from those of other inhabitants. (Valerie G. at Honeywell Labs is working along these lines.) Relevant variables include time profiles for waking/sleeping time, eating, bathing, entertainment, etc.

Regardless of the sensors used, certainty will be less than 100%, so some explicit probability model seems appropriate. Bayesian updating offers a rational approach. All hypotheses about client location are considered and are actively reweighted as new evidence is added. The evidence may take many different forms. ☞ We have a responsibility to provide a framework for sensor fusion.

How Good Must We Be?

Finally, and importantly, the apparent requirements for client unique ID and tracking that this author has been able to glean do ***not*** generally require high accuracy for location. Knowing which room of the house the client currently occupies is usually sufficient. In a few cases, we wish to verify which person performed a particular operation on some fixed facility (door, stove, cupboard, toilet, bed). In these cases, it may be possible to use special sensors that work at close range to these facilities to supplement room-scoped sensors. Examples are tag readers (ID1, BC1), voice activated controls (VR2).

Positive identification of the client in a multi-person household ***is*** a firm requirement however. This means that techniques such as conventional motion sensors, which indicate any moving body, will be of limited value unless supplemented heavily by other methods.

Suggested Laboratory Configuration

The feasibility of much of this technology in the home environment is currently conjectural. For experiments in the research program, we should install a mix of device types mentioned in a laboratory setting. The mix should ideally include:

- Commercially available RF/IR tag system, such as ELPAS, RoamAlert, etc.
- Camera based system for face recognition in one or two key locations.
- Speaker voice identification system on one or two devices.
- Camera system for client tracking in one large room.
- Advanced acoustic transponder system, e.g. bats in one or two rooms.
- Biometric switches, such as fingerprint activated device, on one or two facilities