Finding Lost Objects: Informing the Design of Ubiquitous Computing Services for the Home

Rodney E. Peters[1], Richard Pak[2], Gregory D. Abowd[1], Arthur D. Fisk[2] and Wendy A. Rogers[2]

GVU Center
College of Computing[1] and School of Psychology[2]
Georgia Institute of Technology
Atlanta, GA 30332 USA

ABSTRACT

Factors that influence the finding of objects can be numerous and complex. Ubiquitous computing solutions for this problem begin with underlying technologies (location-sensing and capture) as building blocks for real applications. This paper investigates the real-world nature of what losing an object means and the strategies used to find those objects. A comprehensive survey on the nature of finding lost objects provides insights for the design of human-centered, object-finding services. A systematic analysis of the responses showed the importance of identifying object types, timescale of use, supporting situational factors (reasons for loss and strategies of recovery), and targeting an age-defined user population (user desire and degree of support) when building these services. These criteria motivate a checklist for systematically evaluating both existing and proposed lost object finding services.

Keywords

Assistive technology, location-sensing, automated capture, field survey, usability, age, home environment

INTRODUCTION

Factors that influence the recovery of a lost object can be complex and numerous [1]. People often comment that an important item cannot be found just when it is needed most or that an object that was recently used cannot be found. People think of lost objects as "things that are not where they are supposed to be". Finding the object is unlikely or at least, has very low probability without some effort expended to search the places that may "hide" it.

Building services that can help people keep track of where important objects are located has been gaining momentum in academia and industry. These technologies are being built to support very specific techniques having limited human interactions and representing niche solutions for specific situations. Of the studies that have been conducted, many have focused on the workplace in situations that are supported by mobile computing infrastructures [5,6,7,11,16]. Despite the excitement of the innovation that is occurring, these solutions fall short of providing real support for the challenges that healthy, independent adults, young or old, face in adapting to the dynamic environment of the home. Often, these technologies fail to identify the object characteristics and strategies of the user that influence the usage of technology in finding the lost object. We are interested in answering the questions of why people lose objects, what objects do they lose and what strategies are used to find them to inform the design of object locating services.

The outcome of this research is important for several reasons. First, it is important to determine if the activity of losing objects results in different strategies for different types of objects. While losing one's glasses or the television remote control may be a minor annoyance, losing one's medications or other vital object could lead to personal injury or hardship. Consequently, search strategies may differ for the latter items, compared to the former.

Second, assuming that losing objects is a problem based in memory failures, older adults may be more prone to losing objects than other age groups. An active, older adult living independently in a dynamic environment may, to remain fully functional, adapt behaviors that compensate for deficits brought about by the aging process. However, it is not known if older adults, due to normative decline in memory, exhibit the problem more frequently [2,3].

Third, a thorough characterization of the problem allows us to formulate guidelines to evaluate currently available and proposed services of the future. We also seek to determine whether different age groups perceive this as a real and serious problem or simply a nuisance of everyday life of little consequence. The former would indicate the possibility of specific solutions tailored to specific age groups while the latter would indicate there would be little motivation by a group to use technological solutions to ameliorate the problem.

And fourth, knowing what types of objects are typically lost in the home environment has direct implications on building a service that can be constructed from existing ubiquitous infrastructures (location-sensing and capture). Objects have different form factors, usage patterns and use

frequencies possibly necessitating different object-finding services.

Overview of paper

Describe the survey, then the results structured to answer 5 primary forms of information about the problem, then develop a checklist and then perform a systematic evaluation via this checklist. The contributions are the results that characterize the extent and flavor of the finding lost objects problem as well as a method for evaluating any potential solution for it efficacy.

METHOD

Survey

An initial survey was distributed to assess the effectiveness of the survey format and to allow us to gather information about the behavior of losing objects. 48 of approximately 250 surveys were returned. Specific comments from the surveys were used to guide the development of a comprehensive survey that thoroughly assessed the behavior of losing objects and captured the perceptions of what technology characteristics may be of importance.

Materials

The study questionnaire consisted of a combination of open-ended, short-answer and multiple-choice questions. The questionnaire was designed to collect five primary types of information:

1. Demographic information (age, living arrangement).
2. Who loses objects and why.
3. Characteristics of objects people lose.
4. Strategies used to find objects.
5. The perceived properties of a technological service.

This information informed our analysis of the data, including the development of a coding scheme for understanding the results of the open-ended questions.

Participants

71 participants completed questionnaires. The participants ranged in age from 20 to 80 years of age with the mean age being 55 (*SD*=18.9). The participants were classified into three age groups: 14 participants into the young adult category, 21 into the middle-aged category, and 34 into the older adult category. The mean age of the younger, middle-aged, and older participants was 27 (ages 20 to 33, *SD*=4.0), 45 (ages 37-53, *SD*=4.7), and 72 (ages 56 to 80, *SD*=5.2), respectively. There were 37 female and 34 male respondents.

Two main sampling methods were used to obtain completed questionnaires. Some questionnaires were distributed in public locations (e.g., malls, churches, businesses). These questionnaires included pre-paid postage for the participant to return the completed questionnaire. Other questionnaires were administered to individuals (older age group, N=27) that were participating in a psychological study at a local university and received $5 compensation. We should note that this older adult group was selected from an existing study population and may be considered a high functioning group. Older adults in the general population may have greater difficulties finding lost objects than those articulated by the survey group.

RESULTS

Coding Scheme and Stability of Coding

Two data coders independently analyzed the short-answer responses from the questionnaire using a coding scheme. The coding scheme consisted of five dimensions that were determined to be of research interest:

1. Strategy Properties
2. Object Properties
3. Losing objects – reasons for loss
4. Finding objects – recovery strategies
5. Service Properties

The participant responses were coded along the five dimensions. The stability of the coding was determined by calculating the percentage agreement between the two coders [13]**.** The inter-rater reliability was above 90% for all five dimensions.

Additional coding was performed when data were seen to be collecting into sub-dimensions. We found that it was impractical to anticipate every possible category of response from the respondent for the initial coding scheme definition (e.g., types of strategies). New sub-categories were constructed as they were identified. Again, inter-rater reliability over 90% was achieved in all subsequent coding of newly identified sub-dimensions.

The participants generated 942 coded responses over the five primary dimensions of the coding scheme. Approximately 8% of the 942 statements pertained to objects that are lost, 9% were related to the participant's perceptions of why they lost objects, 23% were strategies that are used to locate lost objects, 18% were related to how objects were found and 42% were related to properties of a hypothetical service to help locate lost objects.

In the remainder of this results section, we will present answers to the five basic categories of information that were the goals of the study

Additional Demographics

Whether someone lives alone or has a roommate could influence what types of objects are lost or the strategies used to locate it. Due to this concern, it is important to understand the living situation of the participants. Younger and older adults primarily reported living in a dormitory/apartment/condominium (62% and 69%, respectively) while middle-aged adults primarily lived in a house (81%). A large portion of all three age groups reported that they did not live alone (young adults, 85%; middle-aged, 81%; older adults, 69%). Most young adults were single (54%) while a major portion of middle-aged and older adults were married (67%, 53%, respectively). Older adults results also showed a divorced/widow frequency of 41% as compared to the young (0%) and middle-age (19%) groups.

Who Loses Objects and Why

Who Loses Objects

As expected, a significant percentage of the respondents admit that finding lost objects is a concern of everyday life. When participants were asked how they felt about the statement, "losing objects is a recurring problem for me," 43% of the young adults, 38% of the middle-aged adults

and 22% of the older adults agreed. In terms of their perception of the burden on their lives (i.e., time spent searching for a lost item), 21% of the young adults, 45% of the middle-aged adults, and 23% of the older adults felt that they spent too much time looking for lost objects.

The perceived need for assistance in the home for a service to help find lost objects was 46% for young, 29% for middle-aged, and 30% for older adults. Interestingly, when asked if they perceived a need for someone else to have a service, 100% of young and middle-aged, and 50% of older adults indicated they knew someone who would benefit from such assistance. This result may be an indirect indication of the extent which losing objects is a problem but is neither recognized nor acknowledged.

Why Objects are Lost

The reasons for losing objects were distinguished by categorizing the responses in terms of the user losing the object under circumstances that they can control (inattentiveness, distracted, time pressure, and memory-related) or from external influences they do not control (object not visible, object moved, clutter). As shown in Table 1, the reasons why participants reportedly lost objects tended to differ across age groups. The most frequently reported reason for young adults was inattentiveness (65%), for middle-aged adults inattentiveness (31%) and clutter (27%) were the most often reported whereas for the older age group the most common reasons were memory-related (24%) or distraction (20%).

Note that for the older age group, "Other" represents responses that were unclear in terms of their placement and insufficient in frequency to create another subcategory. Representative answers were "sheer dumbness" and "it was a new object and I had not made a place for it yet." It is unclear whether these responses have implications in designing a finding lost object service for the home.

In summary, these data indicate that the reported reasons for losing objects seem to differ as a function of age and from a design perspective, the most supportive service is may not be the same for all age groups.

About Objects People Lose

What Objects Are Lost

To determine what objects are typically lost, the participants were asked to name an object they had lost. We found that a variety of objects were given and that they could be placed within two distinct categories: personal or single user (e.g., paper, glasses, wallet or purse, N=43), and shared use or multiple users (e.g., keys, remote control and cordless phone, N=28). The results are unclear if form factor is an indicator of the likelihood of losing the object but may be a limiting factor in choosing an object-finding service that would help recover it.

The participants' responses also revealed a distinct difference in the type of objects lost by age group. The results indicate that personal objects were lost more frequently by the middle-aged group (68%) than by the young (25%) and older (37%) groups.

Age Group	Reason for loss	%
Young (20-36)		
	Inattentiveness	65%
	Distracted	6%
	Object not visible	5%
	Object moved	12%
	Memory-related	12%
Middle-aged (36-55)		
	Inattentiveness	31%
	Distracted	19%
	Object not visible	4%
	Object moved	8%
	Clutter	27%
	Memory-related	8%
Old (56-80)		
	Inattentiveness	13%
	Distracted	22%
	Object not visible	2%
	Time pressure	15%
	Clutter	4%
	Memory-related	24%
	Other	20%

Note: % is within age groups

Table 1. Reported reasons for losing objects.

Where Objects Are Found

To inform what technologies may be useful in finding certain types of objects in specific locations, we asked where the reported lost items were found. Sixty-five different locations were reported for 71 different lost objects identified. We initially thought that named areas of the house (e.g., bedroom, kitchen) would constitute the majority of answers, but the results indicate a much wider variety of places. Our initial coding of locations was inadequate, resulting in a miscellaneous or "other" category that contained places such as coat pocket, box and laundry. The "other" group dominated the results with a frequency of 75%. This indicates a need for further investigation into categorizing the places where objects are found and will be explored in future work.

Breaking down the results into object type, for personal objects, "other" places had a frequency of 83%. The bedroom was the second most frequent place a personal object was found (8%). For multiple-user objects, "other" places had a frequency of 75% followed by kitchen and bedroom, both at 8%. For objects other than personal or multiple-user, the frequency of "other" places was 55%.

These results have implications for the development of location-sensing services that help find lost objects. An appropriate service should be developed such that the typical locations an object may be found can be observed, tracked or identified. For example, a closed drawer and coat pocket present similar problems in sensing the object

(obscuration) but have different requirements (stationary versus mobile).

How Often are Objects Lost

The responses about how often objects are lost were coded into two categories, frequently and infrequently used objects. Frequently used objects were those used on a daily basis and infrequently used objects were not. For those items that are used on a daily basis, roughly one-quarter of the responses indicated that they experienced a loss at least once a week, with little age bias in the response. The middle age group (24%) reported losing frequently used objects only slightly less when compared to the young and old age groups (both 29%). For infrequently used items, 14% of the younger adults indicated a loss at least once a week, versus 19% of the middle-aged adults, and 9% of the older adults. These trends suggest that more frequently used objects are lost more often.

Strategies Used to Find Objects

Responses from the participants showed that there were common strategies that people engage in regardless of age or object type. We identified these strategies as:

1. Retrace search - location(s) are searched based on a sequential order of a person's prior physical locations.
2. Memory search - location(s) are searched based on a person's recall of prior interactions with the object.
3. Exhaustive search - all possible location(s) are searched.
4. Locus search - location(s) are searched where the object is normally to be found.
5. Delegation search - someone other than the person needing the object searches for it.

The most frequently employed strategies to recover a lost object were locus search (33%), exhaustive search (24%) and retrace (19%). The remaining strategies, memory and delegation search were both reported 11% of the time.

Although location search and exhaustive search are primary strategies across age groups, the older adults indicated that they rely far more on retrace (26%) as compared to young and middle-age adults (both 10% occurrence). Note that the delegation search strategy includes the use of technology (portable phone and remote control locators - 2%). This result showed that people seek assistance for searching but may have limited technological choices to use.

Results indicated that the participants were somewhat successful when searching for lost objects. The frequency of always finding the object using a strategy was 57% whereas the frequency of "sometimes finding the item" was 42%. The remaining 1% indicated they usually did not find the object. This suggests that the study participants develop and use strategies that are meaningful and useful in finding the type of object and for the context of the loss situation.

Perceived Properties of a Service

User-perceived Affordances

When asked to describe the characteristics a service, ease of use (23%) and reliability (18%) were the most frequent responses. Representative user responses are, "if it is faster for me to look, why bother" and "if the system can't locate it, why should I use it." Comments describing negative service aspects suggest that persons in the middle and older age groups find high cost (26%) as the most frequent concern. The young age group reported difficulty in using the service (33%) most frequently.

33% of the respondents indicated that the service should work by sounding an audible signal to guide them to the lost object. A visual aid (e.g., light flashing, a map display, picture) was indicated by 10% and 10% indicated that a combination of both techniques would be useful. The responses suggest that the participants didn't think of the service as providing support for their own natural search strategies. They mostly viewed the service as a form of delegation search.

Responses indicated an awareness that the service should be tailorable to the kind of object being tracked ("it would probably depend on the lost object."). Other comments suggested the importance of maintenance and dependability ("NO BATTERIES PLEASE!") and an apprehension toward an intrusive, autonomous system ("don't see how the system could track every item in the house without becoming an intrusive, surveillance-type system.")

Users' Desire for Support

The survey probed the desire for using a service by describing a set of 5 scenarios that are paraphrased here:

1. You are running late and are looking for your keys.
2. The remote control is lost and you can usually find it in less than 10 minutes.
3. Someone you know loses important objects (e.g., medicine) and needs assistance finding it quickly.
4. Someone else has the service and it is reliable but has a steep learning curve.
5. You have the technology and it is helpful but it is difficult to use.

In the first scenario where time pressure is great, 77% of the responses indicated that they probably would want the technology to assist them. In the second and fourth scenarios, there was no clear trend toward usage. The results from the third scenario suggest that service assistance would be valued (71%) as the potential benefits sufficiently outweigh perceived costs. In Scenario 5, the data suggests a trend toward non-use across all age groups (47% would quit usage, 36% unsure).

PARAMETERS FOR EVALUATING TECHNOLOGICAL SOLUTIONS

In addition to understanding the nature and severity of the finding lost objects problem, we want to provide concrete advice for assessing and designing technological assistance. We can interpret the results of the survey as suggestions for a number of design parameters by which any existing or proposed solution should be judged. These parameters are the object type, use timescale, and situational factors. All of these parameters can be used to predict the overall utility of a given technological solution.

Object Type

Object type is defined as whether it is used by a single individual or multiple users. Objects that are used by multiple users may require an infrastructure that could detect the object's position in additional locations and track

multiple users' movements. Although analyzed indirectly from the compiled list of found objects, form factor can be a limiting characteristic for choosing the appropriate location-sensing infrastructure. Certainly, a jumble of keys has a different form factor that a paper sheet or a pair of eyeglasses. For example, consideration of the volume and surface area would be required when: 1) tagging or marking the object; 2) incorporating transponder circuitry, or; 3) recognizing the object in captured video.

Use Timescale

Use timescale consists of the object's frequency of use and the urgency of its recovery. We found that frequently used objects (e.g., keys) were lost more often than infrequently used objects (e.g., tool), for all age groups. Shorter time periods of captured activity may be all that is required to find frequently used objects. Conversely, finding an infrequently used object may require a longer period of captured data if a time or location reference point from which to start searching is unknown. Urgency of recovery also contributes to timescale considerations. Prompt recovery of an object may not occur if the service requires the user to scan long sequences of video whereas a service that uses audible paging may help locate the object quickly.

Situation Factors

Situation factors, the perceived reasons why objects are lost include individually controlled behaviors (e.g., inattentiveness) and external environmental conditions (e.g., clutter). The implications of these factors influence the choice of search strategies. If the person has no recollection of interacting with the object then a complete history of prior activity may be needed (exhaustive search). Yet if there is some memory of the object's location then searching remembered places may be sufficient (location or memory search). In summary, the service may need to capture the user's activities and object interactions as well as the dynamics of the home environment (human or otherwise) that might contribute to losing the object.

EVALUATING TECHNOLOGICAL SOLUTIONS

The parameters for evaluation can now serve as a checklist for evaluating both existing and proposed technological solutions for finding lost objects. These solutions take advantage of two key ubicomp technologies, location sensing and automated capture. Hightower and Borriello provide a useful taxonomy of location-sensing technologies [4]:

1. Triangulation measures distance to an object.
2. Scene analysis captures a scene and from the observer's view compares its features from a stored object dataset.
3. Proximity detection use techniques to determine when objects come near a known location.

Truong *et al.* [14] survey the technologies and applications of automated capture. The underlying technology of automated capture includes devices to record audio, video and writing. The infrastructure records and allows replay, often facilitated by contextual cues (e.g., based on metadata indicating location or timing of activity specific human interaction, locus of activity, reference time).

The solutions we explore below are not intended to be an exhaustive list, but rather a representative sample in this rich domain. We will evaluate three available services and two proposed solutions.

Critiquing Existing Solutions

Audio Paging

In this scenario, we describe a common proximity detection service that is now commercially available and has been the focus of some research at the Bath Institute of Biomedical Engineering [8]. A transponder is attached to an object that will respond to a signal sent from the service's base station. The base station provides a user interface that displays a picture or label and an adjacent button that corresponds the object to be located. When a button is depressed, the base station sends an inaudible signal to the transponder and an audible tone is emitted in response. The user must listen for the tone to find the object's position. The transponder does not store information about the object nor its location. The existing examples of this service are limited to supporting a small number of objects. Each object has its own specific base station signal and audible paging tone. When the object is found, picking up or moving the object will turn off the audible tone of the attached transponder. If the device is not found within a set period of time, the audible tone will automatically turn off causing the user reinitialize the finding process.

Whether the object is an individual or multiple user type is not a consideration for this service. If the object is moved out of detectable range, the service is ineffective. If the base station's effective range covers the entire house, this mitigates the likeliness that the object will be moved out of range. Form factor is also an important consideration, as the transponder must be attached in some manner to the object. As the service is limited in the number objects it can find, the user may have to decide which objects have priority for use with the service.

Use timescale considerations can affect service usage. Although a past memory of the object may not be necessary to find an object within range, but it may affect the time needed to recover it. This service is ideal for short timescale searches. It requires the user to walk through the monitored environment listening for the audible tone and finding the object before a timeout occurs.

This service is the epitome of a delegation search. Situation factors for losing the object (e.g., inattentiveness) are minimized but if the object is out of range or cannot be heard, it will not support the other search strategies.

Automated Visual Object Tracking Service

For this scenario we draw on work research done by Nelson and Green on a service (scene analysis) consisting of an infrastructure built using cameras that are located throughout the home [10]. The cameras monitor known locations (e.g., living room table, kitchen table, and countertop). The service uses the cameras' capabilities to take close-up, high-resolution images of the monitored locations. These images are processed to identify objects that have been described in a recognition database. The service is capable of detecting activity within a camera's

field of view. When the activity concludes, the service processes the images to detect changes in the scene to detect object presence or absence. A location database stores the information about image changes and maintains a list of objects that have been recognized. The user can query both the object and the location database using a touchscreen, visual cueing interface. It was designed to answer questions of the current location of a known object.

Object type can affect service performance if the object has been removed or obscured in the monitored environment. If the object cannot be seen, it cannot be recognized (found). Form factor plays a large part in object recognition in that sufficient images of the object must be recorded so that detection may occur. Small and irregularly shaped objects may be hard to visually describe using this method. This type of service can accommodate large numbers of objects but each must be visually characterized prior to initiating finding the object.

Movements of objects can be monitored regardless of frequency if it remains within the service area. However, the service does not track people and cannot provide replay of interactions with the object. If the captured images can provide a history of object movement then a memory search may be supported. Urgency of recovery is highly dependent on how quickly the service can recognize the object.

This service also is indicative of a delegation search strategy. The user places responsibility of finding the object on the service. If the object can be recognized in a captured frame then the reasons for losing the object (individually controlled or external influences) are minimized. However, if the object cannot be seen, the service may support other strategies (retrace, locus and exhaustive) by providing recall of previously captured images.

Responsive Active Tag Service

The research of Ma and Paradiso presents an interesting variation of commercial tagging systems (proximity detection) [9]. In this service, an encoded optical beam (flashlight) is shone around a location and an optical sensor (tag) detects the incident beam. After detection, the tag turns on a green LED indicating it has been alerted and is decoding the information found in the incident beam. If it is the sought object, a red LED will illuminate as an indication of its location. The service has a working range of 3 meters. The tags are kept in a passive state to conserve battery power but multiple interrogations can affect battery life. All of the tags respond whenever the beam interrogates it and produce a response (green and/or red LED). Note that no location-sensitive context data is recorded in the interrogating flashlight or in the object tag. The total number of supported tags is 35 (possible unique object codes).

Form factor is significant in that a tag must be attached to the object. Usage patterns may be different for single and multiple users (more places to be found) but the reader (flashlight) can move throughout the environment attempting to locate the object.

There is no dependency of whether this is a single or multiple user object for this service. Due to the almost serendipitous nature of this service, prompt recovery of the object in an urgent situation may be unlikely. Assuming that the object is in the line of sight of the flashlight, it will be located if the user sees the tag's response. This service fails totally if the object had been obscured from the beam.

The service is effectively acting as an agent in a delegation search. Allowing the person to move through the environment with the service in hand supports location and exhaustive search strategies. To support a memory strategy, a person would need a reference point from which to start searching. The service does not support a retrace search as no record of previous activity has been kept.

Critiquing Possible Solutions

The Personal Experience Loop

This next scenario is more futuristic, though fairly plausible given the advance of capture technologies. Although we have not to this point critiqued a triangulation-based service (they are cost prohibitive for home use at this moment), the following proposed solution provides the location-sensing capability using a GPS receiver. A capture device is worn that continuously records audio and video of their personal experience. The camera and microphone are mounted inconspicuously on the rim of a pair of glasses and are wirelessly connected through a personal area network to a wallet-sized storage device, reminiscent of Wearable Remembrance Agent and Intel's Personal Server [12,15]. This device can store a full week's worth of audio and video, and is also equipped with a GPS receiver and the ability to read data sent from beacons within a 10-meter range. These beacons indicate the name of indoor locations as well as other individuals wearing similar beacons (perhaps attached to that person's own Personal Server). The result is a portable service that records the content of a personal experience as well as some context of that experience (location and who else was near at all times). The storage device also has a small screen and a simple navigation interface for browsing captured video. The video can be uploaded to a desktop computer for archiving. On this desktop machine, a more powerful browsing program is available providing the ability to search the context (e.g., find the last time I was in the kitchen with my spouse) and replay captured video.

In this scenario, the service – a wearable capture device, is not performing any scene analysis and is therefore independent of object type. If the service is pointed toward the object, its location is captured and the interactions the user may have with it. Interactions with multiple users (frequency of use) that may displace the object would also be captured if they occur within the camera's field of view. Captured data is limited on the wearable device to one week's worth. However, archiving is possible by downloading to an external repository. Finding the object may occur more quickly if a starting reference point, temporal or positional, is known supporting retrace and locus searches and indirectly, a memory search, allowing selective replay (perhaps laborious) of captured interactions

that have been recalled the user. This service does not support a delegation search, as the service cannot recognize objects autonomously. If finding the object is urgent and the on-board captured information is insufficient, the delay in finding the object may increase when accessing and searching the more extensive archived audio and video capture streams, assuming they are available. Note that access to the extended archive is limited having no remote access (desktop availability only).

If the Walls Had Eyes

We assume a fixed, distributed infrastructure for recording audio and video using an array of cameras and microphones in this scenario. Every inch of a person's daily personal space (home, car, office) is within range of at least one camera and microphone. Each recording device knows its location and is equipped with a wireless beacon that can transmit location information to a small, portable device the person wears, creating a trace of where the individual has been relative to the recording devices. All of the captured video is stored on a secure, distributed server, allowing authorized individuals to access any portion of the recorded experiences. The result is a service that records the content of experiences for all of an individual's personal space, regardless of whether they were physically located in the space. Using a desktop GUI, an authorized individual can browse captured video, selecting any camera viewpoint and listening to the associated audio. The trace of a user's location provides the ability to do a limited context search through the captured experiences. A user can augment the search by merging their context trace with that of other individuals (e.g., spouse and children).

Similar in the components to the previous example (cameras, microphones, and wireless beacons), this scenario differs in that it represents a fixed system infrastructure. This system is dependent on object type. Multiple user-object interactions necessitate the need to capture different user locations in which object interactions may have occurred. Form factor only indirectly influences the properties of the system in that sufficient video resolution to resolve the variety of lost objects (as reported by the survey participants) is needed.

This service differs from the previous mobile system in that every inch of the person's personal space has been captured using audio and video sensors regardless of whether the user is located within it the monitored environment. As the primary reasons given for losing an object were inattentiveness, distraction, clutter and memory-related uncertainty, this service supports and augments the abilities of the user by capturing all of the activity that occurs within sensor range independently of user position.

And, this supports retrace, locus and exhaustive searches over varying timescales. A memory search is supported by allowing playback of captured activity to the point of recalled interaction with the lost object. Delegation search is not supported, as the service cannot locate the object autonomously. Trace position data from personal beacons also contribute the user scoping the contribution of captured context stream records. Access and recall is more available through a secure, distributed server allowing the user to search for an object though they may not be present where they believe the object was lost. This would increase access and speed playback providing faster recovery of an object that was urgently needed.

CONCLUSION

We have presented an investigation of the everyday phenomenon of finding a lost object to inform how assistive technological solutions should be designed. The results of a survey have highlighted the extent to which this is a problem for different age groups and the relevant characteristics that define a loss situation.

Young and middle-age groups perceive the problem of finding lost objects as more of a recurring a problem than older adults. Also, perceived reasons for loss and the search strategies adopted differ across age groups. This suggests that age-specific solutions to finding lost objects should be considered.

We discovered a variety of search strategies. One option is to delegate responsibility for the search to another person, and many technological solutions can be positioned as "agents" that are the recipient of this delegation. As promising as this might seem, it is important to design solutions that provide backup strategies that reflect the natural strategies of the individual. These strategies rely on recall of an individual's location (retracing), the object's location (locus), both (memory) or none (exhaustive). These technological services can be assessed based on their ability to track the location of people and objects and replay histories of this information. Additionally, the number, variety and form factor of the objects accommodated, the timescale over which a service works and the internal or external factors influencing the loss situation important considerations. These issues comprise a checklist for assessing any existing or proposed solution.

We demonstrated the assessment of technological services by examining five existing and proposed solutions for finding lost objects. A general conclusion we reach is that while location sensing supports delegation and has the potential to meet urgency needs when it works, it is limited in the number and variety of objects tracked. Capture technologies do not suffer from the same object limitations, but don't meet urgency needs and require some form of location sensing to track people or objects to be practical. We conclude that the most robust services will be hybrids that merge automated capture with location sensing, combining the delegation strategies for urgent and valuable items with a fallback to support the natural, but more time-consuming methodical search strategies of the individual.

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