You're Getting Warmer! How Proximity Information Affects Search Behavior in Physical Spaces

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ABSTRACT
This paper describes the results of a Wizard of Oz study of people's search behavior using BuddySystem, a proximity-sensing system designed to help end-users locate people, places, and things. BuddySystem uses distance estimation based on signal strength alone, since direction is difficult to obtain in ad-hoc radio-based systems. Overall findings indicate that the BuddySystem changed people's search behavior to reduce walking area, but may increase search times if the system demands too much of the user's attention, suggesting that reducing distractions and adjusting search strategies could improve search effectiveness of proximity-based tracking systems in physical spaces.

Keywords
Proximity sensing, Wizard of Oz, BuddySystem

INTRODUCTION

Sensor-based technologies are being used to find lost or kidnapped children, avalanche victims, stolen cars, and other valuables outdoors [1, 5, 8, 9]. Some indoor tracking applications depend on location-sensing infrastructures such as RF beacons and Ultrasound [5, 7, 8, 9], which cannot be readily assumed for most building environments today. Consequently, various proximity-sensing systems have been used to complete item locating tasks [2, 3, 6].

Proximity-sensing technologies such as ad-hoc RF sensors introduce fundamental constraints on the design of a tracking system for users conducting search tasks. These sensing devices can only estimate distance based on signal strengths and often with much uncertainty due to environmental effects such as RF reflection [4]. Direction is difficult to obtain due to the lack of a third fixed point of reference besides the user and the object.

Previous work in proximity-sensing applications do not address the impact such a system has on people's search behavior nor do they address how users may deal with the error prone RF sensor-data. In this paper, we describe a Wizard of Oz study of people's search behavior using BuddySystem, a proximity-sensing system modeled on the Berkeley Smart Dust sensors [3].

BUDDYSYSTEM PROTOTYPE

BuddySystem is a prototype proximity-based tracking system designed to help end-users conduct search tasks. Originally inspired by extensive field studies with firefighters, the system was designed to increase firefighter safety by helping pairs maintain proximity in structure fires where visibility and hearing is limited. The PDA-based BuddySystem displays distance of objects within a range of 40 feet in 10-foot increments. We expected users to wander through the space and to read the BuddySystem as a "warmer or colder" indicator, monitoring proximity increase or decrease. Using the model described in [4], the BuddySystem prototype simulates error in distance estimation by up to 10 feet, and adds a random noise filter delay between 5-10 seconds on the average.

We designed and evaluated three different interfaces for BuddySystem. Interface "A" presents all tagged items categorized by type (i.e., person, place, or thing) and a line, representing the item's range of proximity [Fig. 1]. "B" presents items in increasing distance categories and does not display items out of range [Fig. 2]. "C" presents tagged items in decreasing distance categories like a radar display with curved cutoffs separating the distance categories [Fig. 3]. Each of the three interfaces below reports Lucky D., a student, is zero to ten feet away from the user.

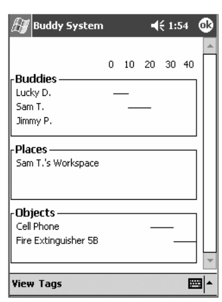

Figure 1. Interface A

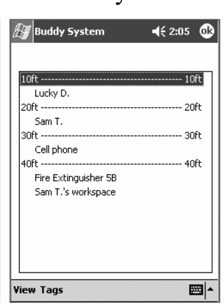

Figure 2. Interface B

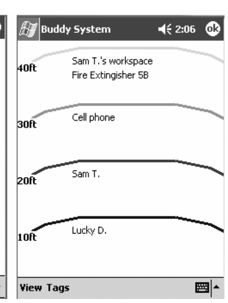

Figure 3. Interface C

To simulate the RF sensor-data, we designed a Wizard of Oz Controller interface that consisted of a map of an office building floor with movable dots, representing items tagged with RF sensors. Using a laptop equipped with 802.11b wireless LAN, a wizard followed the user throughout the building and updated sensor locations by moving dots on the controller interface, which then generated new sensor readings for the users.

EXPERIMENTAL DESIGN

Subjects and Experimental Conditions

We had 18 subjects ranging 20 to 30 years of age, half of whom owned PDAs. One third of them were unfamiliar with the physical search space so we chose a building with a simple floor plan. Subjects used the system for a few minutes and were then given three tasks: locate a specific office, a teaching assistant, and a lost cell phone placed somewhere on one floor of an office building. All objects were placed at a random, stationary location. These tasks were chosen because they would require subjects to search for a place, a person, and an object, each of which could require unique search strategies due to differences in visibility, mobility, and possible locations. Each subject completed the tasks using two of the three BuddySystem interfaces and once without BuddySystem support to provide a baseline. Without BuddySystem, users would rely upon their own senses as they searched through the space.

Metrics

To assess the effectiveness of the different interfaces, we measured task completion time (T) and shortest walking distance between starting location and item location (D). Because each subject had a different starting location and item location and because each subject was expected to walk around the space while checking BuddySystem for proximity updates, we assessed effectiveness of search by calculating the task completion time divided by the shortest walking distance (T/D). Comparisons were made within subjects to determine whether the person did better or worse with BuddySystem than without. Observations included search strategy, walking speed, footpath, and amount of attention paid to the BuddySystem. Subjects were also asked to describe their search strategies.

RESULTS

Using the T/D metric, our results show that, out of 104 cases, in 42 cases the subject performed better while using a BuddySystem than without and in 62 the subject performed worse. There were no significant differences observed between the BuddySystem designs or between searches for different types of items. The system drastically changed the way subjects searched for the items. Without the BuddySystem, subjects would wander around, looking for items in a sweeping manner. With the BuddySystem, a common strategy was to walk around quickly until the item came into range. Then the subject would slow down until the item was found. Subjects would also zigzag around the item location, turning around when the proximity decreased. Most subjects who performed better with the BuddySystem utilized these two strategies. Another strategy used by some subjects was triangulation. Similar to mathematical triangulation with three reference points, some subjects watched the changes of distance to guess the direction of the item. This strategy led to narrowly focused attention upon the interface that caused subjects to walk right past obviously visible items. Subjects particularly preferred support from the BuddySystem when searching for objects of low visibility such as the cell phone.

DISCUSSION

The choices of search strategy and amount of attention focused upon the interface have the largest impact on the effectiveness of the BuddySystem. With the BuddySystem, search strategies become more focused, but may cause tunnel vision. Subjects that used the system to complement normal search patterns were more at ease and performed better with the system. Effective search strategies such as adjusting walking speed to proximity and zigzagging decreased the time spent wandering and compensated for lack of directional information. These search strategies allowed for visual search of the environment and improved search efficiency. Overly attention-demanding strategies such as triangulation decreased search efficiency.

CONCLUSION AND FUTURE WORK

Future designs of proximity-sensing systems for searching physical spaces should minimize distraction from visual search techniques and should support effective search strategies such as adjusting walking speed or zigzagging. We plan to improve the BuddySystem design to support more complex search tasks such as finding moving items. We will also examine domains where proximity-sensing based search support may be useful such as locating rescue personnel in emergency response operations.

REFERENCES

1. Back Country Access. Available at http://www.bcaccess.com/
2. Falk, J., Ljungstrand, P., Bjork, S., and Hansson R. Pirates: Proximity-Triggered Interaction in a Multi-Player Game, in *Extended Abstracts of CHI '01* (Seattle, WA, March 2001), ACM Press, 119-120.
3. Kahn, J. M., Katz, R. H., and Pister, K. S. J. Next Century Challenges: Mobile networking for Smart Dust, in Proceedings *of Mobicom '99* (Seattle, WA, August 1999), ACM Press, 271-278.
4. Klemmer, S., Waterson, S., and Whitehouse, K. Towards a Location-Based Context-Aware Sensor Infrastructure. Internal report available at http://guir.berkeley.edu/projects/location/Location.pdf
5. Lojack. Available at http://www.lojack.com/
6. Ma, H. & Paradiso, J. A. The FindIT Flashlight: Responsive Tagging Based on Optically Triggered Microprocessor Wakeup, in *Proceedings of Ubicomp '02* (Goteborg, Sweden, Sept 2002), ACM Press, 160-167.
7. Priyantha, N. B., Chakraborty, A., Balakrishnan, H. The Cricket Location-Support System, in *Mobicom '00* (Boston, MA, Aug 2000), ACM Press, 32-43.
8. WOZ. Available at http://www.wheelsofzeus.com/
9. Wherify. Available at http://www.wherifywireless.com