TagRadar: Locating Objects Using a Smart Phone Accessory

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Abstract
TagRadar is a smart phone accessory that helps users to locate objects with radio frequency tags. We employ a directional antenna and combine signal strength readings with headings obtained from the compass of the smart phone. While scanning a space by waving the smart phone, the aggregated data is presented on an on-screen polar graph that dynamically reveals the most likely heading of the target object. A user test showed that users favor TagRadar and that it is both faster and has a higher accuracy compared to using only signal strength.

Author Keywords
locating things; smart phone accessory; RSSI

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous.

Introduction
Tracking and locating objects is important in many situations. In manufacturing and transport industry, tags are indispensable to follow objects through a process. At home, people misplace or forget the location of items for a variety of reasons [3], including inattentiveness, distraction or memory problems and it occurs at all ages. A popular strategy (70%) for finding things involves

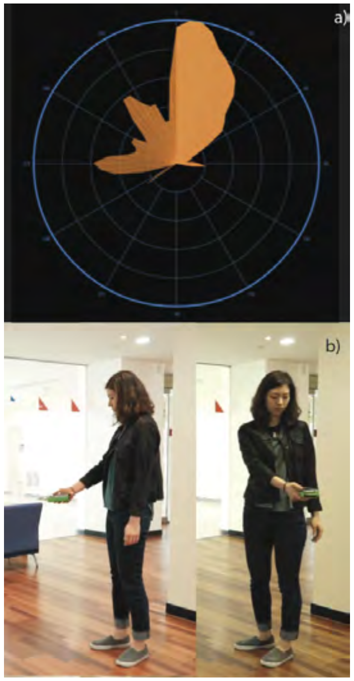

Figure 1: The on-screen user interface a) shows the relative signal strength in a polar graph and reveals the heading of the target when the user is sweeping a space b).

physically moving through space to find the object, which is inevitably time consuming.

Several technical aids are presented to help users find things and the solutions span multiple modalities. The FindIt flashlight [5] uses optical triggered tags activated with a flashlight, but requires line of sight. Sound is a popular method to locate lost items, several commercial system exist with tags that can make sound. However, with a trade-off between size, battery, commercial implementations such as Tile [8] need to be in a quiet environment to actual hear the sound.

With the advent of the Internet of Things, more and more everyday objects are enabled with radio frequency (RF) communication. Using Received Signal Strength Indicator (RSSI) to find objects is a common approach and several applications use it to provide feedback on the proximity of objects. Using a single radio is in real world situations RSSI is unusable due to reflections [1, 2]. Most projects [6] make use of several calibrated beacons [7, 2]. A few related work uses antennas diversification to estimate the heading of an object. For instance, a combination directional antennas [4] allow a robot to locate objects tagged with RFIDs.

TagRadar provides an approach to locate items with RF and a single radio that does not require a prepared space with beacons or similar technology. It is particularly useful in scenarios when audio feedback is not possible, as commonly shown in the related approaches. TagRadar combines a single directional antenna to measure signal strength with the Inertial Measurement Unit (IMU) of the smart phone. When the user waves the smart phone around, the combined data is presented on an on-screen User Interface (UI) to indicate the heading of the target object similar to a radar.

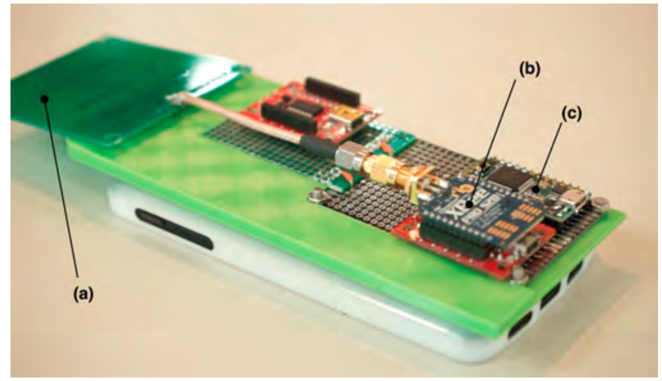

Figure 2: The prototype accessory consists of a 3D printed smart phone cover. The hardware consists of a yagi directional antenna (a) zigbee radio (b) and a teensy arduino (c).

Design

Our smart phone application samples signal strength (20 Hz) to a target object using a directional antenna. Samples are stored and correlated with the absolute heading reported by the phone's IMU. Collected samples are binned per 5 degrees of heading, and a moving average and median filter is applied per bin to reduce fluctuations.

When the user waves the phone to scan a space, the aggregated signal strength information is dynamically presented in a polar graph similar to a radar display. The graph is rotated to match the orientation of the phone, so that "up" on the display matches the pointing direction of the phone. As shown in Figure 1, the graph reveals the most probable heading. Sampled data is discarded after 20 seconds and all data is erased when touching the screen, which is useful if the user is moving to a new location.

Early user feedback revealed that, in case of obstructed target objects, the relative difference in RSSI value does not reveal a clear target heading. Therefore, a dynamic mapping of signals was implemented that linearly interpolates the polar graph between minimum and maximum received strength.

Our proof of concept system is implemented on the Nexus 5 Android phone using Processing for Android, shown in Figure 2. A custom 3D printed accessory is attached as a sleeve to the phone and connected through USB. Wireless communication is provided using two Xbee 2 pro nodes (2.4 Ghz). The Xbee on the accessory is connected (RSMA) to a PCB yagi directional antenna with 8.5 dBi gain for 2.4Ghz and an Arduino communicates with the smart phone. The target object uses a standard Xbee with an on-chip antenna connected to an Arduino Fio with a battery.

Performance

We evaluated TagRadar in a user study with 15 users recruited from local universities. We compared the directional antenna (DIR) using the TagRadar software to an onmi directional (OMNI) antenna that only displayed signal strength without heading.

A 5 by 7 meter class room with tables was filled with 24 numbered cardboard boxes, shown in Figure 3. Boxes were placed on two different levels: on and under the table and 6 boxes where shielded with a metal plate. The different levels allow the users to interact with the boxes in different planes and angles of the environment, while the shielding status mimic worst-case scenarios where the radio signals encounter maximum attenuation and reflection. We hid a yellow target object in a box and the user had to locate the target object.

We expected a high individual variability in strategy of finding objects and therefore selected a within subject design: all participants perform both conditions. Carry-over effects were counter-acted by quasi randomizing the order of the condition and by the layout of the environment. Each participant performed 9 searches with each antenna configuration and were timed.

A 'paired sample t-test' ($n=15$) showed that the directional antenna (DIR) ($M=107.15$ $SD=61.03$) was significantly faster than the onmi directional antenna (OMNI) ($M=159.08$ $SD=69.82$). ($t=2.32$, $p=0.039 < 0.05$).

Figure 3: In the user study, users had to locate a target object that was hidden in 1 of 24 boxes in a class room.

As this setup can potentially reduce the finding task to a 1/24 selection task, we included two real world situations by hiding an item in the room. Two participants failed to find the target in the OMNI condition within 300 seconds and where excluded. The remaining 13 revealed that the DIR ($M=81.43\%$) shows significant higher accuracy than OMNI ($M=62.50\%$). ($t=3.68$, $p=0.002 < 0.05$) in pinpointing the location.

We observed that most participants in the DIR condition found an initial direction with a wide sweep of the room. Arrived at the potential location, a second sweep narrowed down the location of the object. In the OMNI condition participants had to walk around the room to test each box for signal strength which was much slower. When asked in a post questionnaire, 70% participants preferred the directional antenna.

Discussion

Tagradar was significantly faster and more accurate in locating objects compared to a naive implementation that directly visualizes signal strength readings. The user study shows that the prevailing strategy of participants was to perform a few wide sweeps to pinpoint the location of the target object. The study also indicates that because of the relative signal strength display, the UI of TagRadar doesn't provide distance information as the omnidirectional antenna does when near to the target object. The current version therefore indicates close proximity by changing the display color when the absolute signal strength value exceeds a value. In the future we plan to employ antenna diversification using both an omni directional and directional antenna to include distance in the visualization.

In this demonstration we focused on finding objects with a human in the loop. In the future we plan to employ TagRadar for other uses, such as on a mobile platform (quadcopter) to map the locations of objects in large spaces where active tracking with beacons is not feasible.

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References

[1] Benkic, K., Malajner, M., Planinsic, P., and Cucej, Z. Using rssi value for distance estimation in wireless sensor networks based on zigbee. In *Systems, Signals and Image Processing, 2008. IWSSIP 2008. 15th International Conference on* (June 2008), 303–306.

[2] Hara, S., Zhao, D., Yanagihara, K., Taketsugu, J., Fukui, K., Fukunaga, S., and Kitayama, K. Propagation characteristics of ieee 802.15.4 radio signal and their application for location estimation. In *Vehicular Technology Conference, 2005. VTC 2005-Spring. 2005 IEEE 61st*, vol. 1 (May 2005), 97–101 Vol. 1.

[3] Kientz, J. A., Patel, S. N., Tyebkhan, A. Z., Gane, B., Wiley, J., and Abowd, G. D. Where's my stuff?: Design and evaluation of a mobile system for locating lost items for the visually impaired. In *Proc. ACM SIGACCESS* (2006), 103–110.

[4] Kim, M., Kim, H. W., and Chong, N. Y. Automated robot docking using direction sensing rfid. In *Robotics and Automation, 2007 IEEE International Conference on* (April 2007), 4588–4593.

[5] Ma, H., and Paradiso, J. A. The findit flashlight: Responsive tagging based on optically triggered microprocessor wakeup. In *Proc, UbiComp '02* (2002), 160–167.

[6] Martin, E., Vinyals, O., Friedland, G., and Bajcsy, R. Precise indoor localization using smart phones. In *Proceedings of the International Conference on Multimedia*, MM '10 (2010), 787–790.

[7] Shah, S., Srirangarajan, S., and Tewfik, A. Implementation of a directional beacon-based position location algorithm in a signal processing framework. *Wireless Communications, IEEE Transactions on 9*, 3 (March 2010), 1044–1053.

[8] Tile a lost items tracker. http://www.thetileapp.com. Accessed: 2015-03-30.