Exploratorium Indoor Positioning System Project — NSF EAGER

Public Outcomes Report

In the 2013 Museum Edition of the New Media Consortium (NMC) Horizon Report, the NMC identified indoor positioning as an emerging technology poised to change the museum field. It was posited that such Indoor Positioning Systems (IPS) would be able to track visitors as they move inside a museum and, thereby, open up opportunities to develop location-aware applications to aid visitor research and enhance the visitor experience.

This EAGER project sought to generate early knowledge for the museum field about the capabilities and limitations of an IPS to: 1) automate the collection of visitor movement data for museum research, and 2) enable location-aware applications designed to support museum visitor learning. Working with Qualcomm, Inc., the Exploratorium installed and experimented with an early prototype of a whole-museum, WiFi-based IPS that acquired and processed timestamped location data (latitude/longitude) from mobile test devices, similar to cell phones. The project 1) defined IPS ground-truth testing protocols for three levels of location resolution: gallery (dozen or more meters), cluster (several meters), and exhibit (one meter or less); 2) tested the reliability of the prototype IPS to collect visitor movement data at all three location resolutions; 3) prototyped and evaluated a location-aware mobile application that allowed visitors to listen to and record "crowd-sourced" comments within a gallery; and, 4) developed and made public tools to assist in the analysis of timestamped latitude/longitude data, which can be adapted to accommodate other types of positioning systems beyond this project's prototype WiFi-based IPS.

Intellectual Merit

Ground-truth test results conducted in this project indicated that the prototype system could reliably locate an individual wearing a tracking device at the gallery level (i.e., determine which gallery the person was in as s/he moved through the Exploratorium). However, these same tests found that IPS gallery-level tracking could be compromised due to interference from high-voltage exhibits or unshielded electronics. Moreover, without complementary technologies (for example, a built-in barometer), the system could not reliably distinguish between a mezzanine and the area below. Finally, accurate gallery location could be challenging at boundaries between galleries.

Ground-truth testing also revealed that despite placing five wireless Access Points (APs) in a small gallery (3500 square feet), we were unable to achieve reliable exhibit-level resolution—we could not distinguish when a visitor was at one exhibit or its adjacent exhibit less than 3 meters away. Several factors made exhibit-level positioning challenging. The lack of hardware standardization meant that different manufacturers' mobile tracking devices and wireless equipment could provide slightly different latitude and longitude coordinates. Location data were sensitive to how the test device was held or worn (e.g., in a back versus front pocket). At best, the prototype system was able to provide cluster-level resolution.

(A preliminary test with an alternative indoor positioning system that used Bluetooth Low-Energy (BLE) beacons placed on exhibits in the same small gallery surfaced similar issues. We were unable to reliably distinguish between adjacent exhibits.)

In general, location accuracy for an IPS depends on the carefully planned physical placement of the APs, geometry of the space, footprint of the exhibits and electromagnetic events. Our tests highlighted the importance of conducting extensive tests as part of any IPS installation to assess adequate resolution and of working closely with the IPS provider to configure the system to optimize performance.

In addition to conducting an extensive set of ground-truth tests, the project experimented with **using the WiFi-based prototype IPS to collect gallery-level movement data for museum research**. A comparison of human observers and the IPS found that while human observers sometimes lost the person being tracked in crowds and became fatigued when tracking long (e.g., 4 hour) visits, the IPS did not. Alternatively, the IPS could lose location data due to electromagnetic events and may identify the wrong gallery when the person tracked was using exhibits at gallery boundaries. Nonetheless, overall the IPS provided excellent reliability for collecting whole-museum movement data at gallery resolution.

This project also prototyped Open Conversations, **a crowd-sourced mobile audio application that used IPS data** to allow visitors to record short comments and listen to remarks left from staff, experts and other visitors according to location. Formative evaluation conducted in a small gallery (3500 square feet) with 26 exhibits, found that the lack of exhibit-level specificity was frustrating and confusing, and points to the importance of exhibit-level resolution for developing a worthwhile visitor experience in a museum like the Exploratorium.

Broader Impact

As of 2016, indoor positioning at higher levels of resolution (better than 2 meters) remains a promise rather than a realization. Yet, increasingly museums are being approached by vendors promising plug-and-play indoor positioning solutions. This project provides museums with techniques for assessing an IPS, tools for analyzing the data it collects, and findings on the potential pitfalls of using an IPS in the museum context—separating hype from reality.