Using BLE Beacons to Simulate Proxemic Surveillance for an Interactive Art Installation

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Abstract
In this paper, we describe the use of Bluetooth low energy (BLE) beacons and floor projections to track participant movements and indicate crossed paths in an interactive art installation. Beacons have typically been used in static locations for broadcasting data to nearby mobile devices. The newer generation of beacons, e.g. Estimote Stickers — with their small size, long battery life, and low cost — make it easier to enhance portable objects with smart capabilities, broadcasting data about environment, location, motion, and interaction with other Bluetooth devices. In the first trials of our installation on James Joyce's *Ulysses* and proxemic surveillance, we chose to avoid interaction through mobile devices, instead making everyday portable objects (and the people who carry them) into 'nearables'. This enabled the tracking of human-human, as opposed to human-object, proxemics. We discuss the advantages and limitations of using small adhesive beacons to capture human-human proxemic data, and effective ways of visualizing these patterns.

Author Keywords
BLE beacons; tracking; ubiquitous computing; interactive installation; art installation; information visualization; surveillance; James Joyce; Ulysses.

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

Introduction

Use of BLE beacons for communicating with proximate mobile devices is on the rise among HCI practitioners and artists. Estimote Stickers, for example, make it possible to add intelligence to objects (personal items, retail goods, museum pieces) and physical spaces (via walls, shelves, tables). When a beacon combines with a portable object, that object may be referred to as a nearable [3]. Apps with nearables support are typically designed around the notion of co-located people and objects, and can be found in brick and mortar retail shops, smart homes, and cultural spaces. In these and other contexts, nearables help to facilitate human-object interactions, almost always with the foregrounded use of a mobile device on the part of the human interactant.

In this paper, we are more interested in the use of BLE beacons to track and display human-human proxemics within a space, namely an interactive art installation, than for use with a static point of interest (POI) display. However, in both of these uses a major drawback exists: the reliance on mobile phone use by visitors in the exhibition space. Mobile devices, while ubiquitous and convenient, are overly familiar to the visitor and may impede immersion in the experience beyond the device [22, 19]. Our installation, North Circular, eschews the use of mobile devices by visitors in the exhibition space altogether. Instead, we use nearables (portable objects powered by Estimote Stickers) and floor projections to capture human-human proxemics and highlight themes of voyeurism and omniscient surveillance in relation to James Joyce's *Ulysses* and online data interactions.

Until now, little has been written on using BLE beacons *in place of* mobile devices to track interactions, i.e. to track users who carry beacons. Nor does the literature reveal use of beacon technologies for monitoring human-human proxemics, although there is a growing literature describing the use of Bluetooth tracking to analyze human behavior in public spaces (e.g. [9, 24, 25]), among other monitoring and analysis approaches and technologies (see Background). In the sections that follow, we discuss the current state-of-the-art in BLE beacon technology, including the use of Estimote Stickers in interactive installations. We then present the North Circular project and digest the feedback collected in our initial prototype evaluation. We conclude with a discussion of small adhesive beacons (and corresponding floor projections and audio), focusing on their role in guiding the installation design. The aim is to capture human-human proxemics and discover compelling ways to visualize the patterns and data generated by these interactions, thereby improving immersion, and achieving productive ambiguity by provoking intrigue, mystery, and delight [10].

Related Work

Proxemics and surveillance

The term proxemics was first introduced by Hall in 1966, denoting 'the interrelated observations and theories of [people]'s use of space as a specialized elaboration of culture' [11]. Interactions between people in a shared space are relevant to this study because of our focus on a particular section of *Ulysses*, 'The Wandering Rocks', which maps crossed paths, fleeting interactions, and intercepted thoughts in Dublin a century ago [1]. Visitors to our installation interact

and interpret the meaning of audiovisual content in conjunction with other participants, as well as navigating and reading the space itself.

While we found no evidence of research on the use of BLE beacons to capture human-human proxemics, our theme shares affinities with other surveillance technologies, including the use of video and other means in proxemics, human behaviour analysis, and social signal processing [6, 26, 23]. The field of surveillance is already at an advanced stage in analysing proxemics and 'sens[ing] and understand[ing] human social signals' [26]; however, such research is outside the scope of this short paper.

Uses of BLE beacons

One of the primary uses of BLE beacons is with POI displays, i.e. 'triggering an action or event once a user comes within a certain distance of a particular physical location' [12]. Beacons are placed on fixed objects such as tables or walls, usually in a retail environment. In this scenario, beacons are deployed primarily to 'provide customers with information about the store's business profile, current offers and discounts', and so that 'the owner can find out which products are the most popular'. Fixed BLE beacons have also been tested in non-retail environments such as smart homes [13] and healthcare facilities [14].

Another use of beacons is 'two-way proximity', in which the user's mobile device is enlisted to track activity. As one article points out, 'The opportunity for marketers (across sectors) to collect valuable insights from BLE beacons is massive: knowing who entered what area, at what time and for how long' [17]. Combined with fixed POI beacons, benefits to retailers are multiplied: 'By installing BLE beacons across a store and combining them with shopping apps built for customers, retailers can identify exactly where in the store customers are located and serve them relevant contextual information.' The same author admits, however, that the 'challenge to overcome is the privacy debate' – a not insignificant barrier, and one that is worth exploring.

In art installations, BLE beacons are mainly used to enhance the visitor experience and track movement through exhibitions. Often this involves using a device (purpose-built or the visitor's own) to scan displays, similar to the way near-field communication (NFC) technology is used. For example, Estimote Stickers have been tested in New York's Guggenheim Museum and the Metropolitan Museum for analyzing traffic flow and supporting virtual tour guides [20]. Recently, some artists have begun using nearables in more dynamic and imaginative ways, such as attaching small adhesive beacons to objects that users carry with them to trigger events in the experience [4], or in more critical ways, such as in Enxuto and Love's institutionally focused work *Beacons* (2016), which analyses how data from beacons deployed in cultural venues, like 'data collected from any social system … is often put into service to shore up institutional agendas' [8].

However, what we found more interesting than simply tracking individual user movements or interactions with the space, or human-object interactions, was tracking (and revealing) interactions between users. Human-human proxemics, as this domain might be called, is an underexplored area of nearables research and one that raises a number of questions. For example, how do interactants work together to interpret ambiguous information in the exhibition space? More broadly, how well do people understand the inherently give-and-take relationship between sharing, surveillance, and data?

Evolving Concept and Implementation

Vision

Joyce's painstakingly mapped 'Wandering Rocks' episode of *Ulysses* presents both an omniscient bird's eye view of Dublin and a multiplicity of subjective views and sounds (both ambient and spoken) of the city, creating an apt metaphor for the heavily surveilled and data rich 21st century metropolis. The characters in 'The Wandering Rocks' interact with each other as their paths cross, listening in and being overheard, observing and being observed, in the social fishbowl that was Dublin a century ago. North Circular — which pays homage to *Ulysses* as a 20th century proto-hypertext for its non-linearity, interconnectivity, and synchronicity [2] — is a temporary art installation that encourages visitors to consider what the multilayered, datafied, hyperconnected city of 2017 might look and sound like as constructed from our own data traces. The experience, which takes place in a dark room, combines participant tracking with interactive floor projections and a sonic environment composed of synthesized social media content and 'stream-of-consciousness' [7] passages from *Ulysses*.

Figure 1: Early concept sketch for the North Circular installation.

Online data can be interpreted in a number of ways. On the positive end of the spectrum, open data can be an enjoyable way of exploring both physical and virtual communities. Nearly everyone who uses social media admits to lurking – the practice of using your account to 'spy' on others without actually posting. So-called 'lurkers' are a majority faction in interactive situations of all types [16]. On the negative end, however, data can equate to heavy surveillance, influencing behaviour and interfering in citizens' private lives, e.g. an emerging social credit system in China that computes citizen scores based on personal credit, social ties, and political affiliations [5, 21]. It is this duality we aim to highlight in our installation. Visitors enter an exhibition space where their movements are tracked, triggering floor projections that align with each user and vibrate when in close proximity with another participant (Fig. 1). These abstract visual projections and their behaviour suggest crossed paths, a strong theme in 'The Wandering Rocks' and a current focus in technologies of proxemic surveillance.

Figure 2: Participants chose from four talismans (a bar of lemon soap, a key, a book, and a potato), each with an Estimote Sticker attached, for carrying throughout the exhibition space.

High-fidelity prototype

Having initially considered video as a means of tracking participants in the exhibition space, we opted for Estimote Stickers due to cost, mobility, and setup concerns. We attached Estimote Stickers to four different objects, referred to in the installation as 'talismans' — all bearing significance to the story told in Joyce's *Ulysses* [15]. Talismans, used as nearables (Fig. 2), camouflage the tracking devices and facilitate greater immersion in the experience than might be permitted with mobile phones. In this way, and because we additionally chose to use Estimote Stickers as non-fixed, to be carried passively by visitors throughout the exhibition space, visitor movements are tracked without the need to download a supporting app or engage with a mobile device. Instead, North Circular uses three of its own Android phones, hidden in fixed locations within the space (Fig. 3), for detecting Estimote Stickers through a process of trilateration (see [18]).

For the interactive floor display, North Circular features two projectors attached to wood mounting structures to visualize tracking data and indicate when two or more stickers are within close range of one another (Fig. 4). Initially, we sought to visualize human-human proxemics by plotting Bluetooth data onto a grid. However, this approach proved visually uncompelling

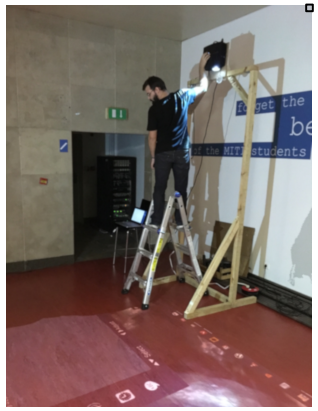

Figure 4: One of two mounting structures for projecting proxemic patterns and data on the exhibition floor.

Figure 5: Floor projection, showing interactants in close proximity and the resulting vibration of waves.

and less well suited to the project vision, showing visitor densities instead of proximate encounters. Ultimately, after some trial and error, we developed a visualization strategy that took better advantage of the data being collected from the Estimote Stickers, while conveying a sufficient degree of productive ambiguity. In this manner, indirect tracking of signal waves is used to indicate the position of visitors relative to the installation's fixed mobile device configuration; the closer a visitor comes to one of the three reference points, the smaller the radius of the resulting signal wave, as projected onto the exhibition floor. Waves, and corresponding Stickers, are represented with different colors and appear to vibrate when visitors come within 50 centimeters of one another (Fig. 5); the more participants within the same small area, the greater the vibration. Numbers flash at irregular intervals in the area where wave patterns overlap, signifying the recalculation of coordinates as the positions of the Estimote Stickers change (Fig. 6).

Finally, North Circular features a sonic layer that interweaves social media tweets and 'missed connections' with stream-of-consciousness passages from 'The Wandering Rocks' using both directional and stationary speakers. Social media content is presented in the form of high quality, locally accented text-to-speech fragments to depict the city's psychic layer with aural impact. These media represent the public (external) voices, physical or virtual, that one encounters in the man-made soundscape of a city, while the stream-of-consciousness passages add an interior dimension. As we browse the Internet, we are, in essence, internalizing others' thoughts. What feelings emerge when those fragments are spoken aloud instead? Is it strange to hear vocalizations of text features such as emojis or hashtags? Whose data are we listening to?

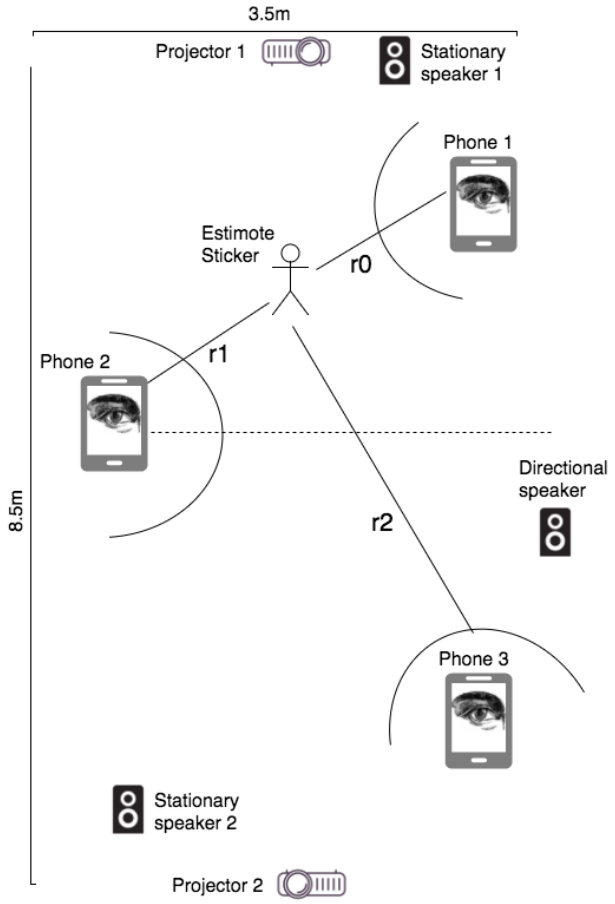

Figure 3: Installation diagram, showing projector and speaker setup, along with hidden, fixed Android phone configuration and trilateration system for detecting Estimote Stickers.

Figure 6: Close-up of floor projection, showing vibrating wave and dynamic repositioning of the small adhesive beacon.

	Day 1	Day 2
F **M**	1 1	5 6
Age	1*25-34 1*35-44	2*18-24 7*25-34 1*35-44 1*55-64
Min. Ed.	2*PhD	4*BA/BSc 3*MA/MSc 4*PhD

Table 1: Gender, age, and minimum education level of user study participants.

Evaluation

We evaluated the effectiveness and aesthetic appeal of the installation by conducting exit surveys with 13 participants over two days of testing. On Day 1, after a trial involving just two participants (Table 1), we received feedback describing the installation as 'an emotional experience of a dystopian world'. However, we quickly realized the interactive element was not clear enough. One participant commented: 'The projections looked like electromagnetic waves, but I don't think they related to my movements', while the other stated that the projections 'seemed not to be affected by me'. Based on this feedback, and prior to testing on Day 2, we calibrated border values to better detect proximate stickers. However, readings continued to cluster in the lower range, making it hard to distinguish the distance to each reference point. We addressed this by adding a path through the exhibit and using the raw data being collected to show patterns and values in a state of 'hyperactive' animation throughout the experience.

These measures proved successful: participants on Day 2 understood their motion and interactions to have an effect on the visualization. Despite the fact that the interaction suffered some technical glitches, participants correctly guessed the behavior of the wave projections in relation to the beacons: 'they move with the objects in our hands'; 'they change according to the position of the tagged object in our hands'; 'circles change size according to our position'; and so on. Audio was still an issue: several participants said they ignored the audio to focus on the visual - 'I didn't pay attention to the audio, I was trying to find out what the lines meant'; I focused on the lines and lost the notion of sound' - while others complained that audio and visual components were insufficiently integrated.

Discussion and Future Work

As shown in the video, once interactivity was enhanced, participants began to play with the installation and work together to find connections and decipher meaning. Participants tested the boundaries of how waves responded to being closer or further from the reference points and other people, and questioned how the objects, sound, and floor display fit together. The installation's 'puzzle' was not entirely 'solved' during testing, nor were easy solutions offered, but there was enough of what Gaver et al. call productive ambiguity [10] to incite curiosity and participation in the 'game'. One participant liked how 'it responds to proximity and demands interaction with each other'. It is worth noting that none of the participants got out their mobile phones during testing; all were immersed in the experience without resorting to an intermediary device.

Estimote Stickers lived up to their promise as a cost-effective, easily transportable, subtle, and adaptable means of doing indoor tracking. They enabled us to bypass mobile phone use by participants, and they offered a fairly effective means of observing and representing human-human proxemics. The main drawback in our study was most likely due to weak signal strength on the part of the Android phones used as reference points. This could be addressed by replacing them with more expensive iPhones or designing for a smaller space. Future work will involve the use of a stronger antenna, focus on improved integration of audio and video components (using sensors to rotate the directional speaker in sync with beacon data), and providing context for the visitor (through an informative entrance display).

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