# Ambient Storytelling Experiences and Applications for Interactive Architecture

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***Abstract*—This paper explores ongoing research into *ambient storytelling* experiences and applications for the built environment and presents a design prototype for Place-based, Ubiquitous, Connected, and Kinetic (PUCK) interactive architecture. Through the use of ubiquitous technologies, it is our goal to enhance environmental awareness, augment presence in the physical environment, and enable participation through ambient interfaces. This research specifically investigates ambient storytelling through responsive environments, and explores how buildings can act as animate storytelling entities that engage and interact with their inhabitants.**

***Keywords- Ambient Storytelling; Environmental Media; Interactive Architecture; Lifelogging***

## I. INTRODUCTION

As ubiquitous computing research had predicted in the early 1990's [1], embedded computing technologies and mobile devices have become part of our environment [2], making it possible to widely connect people to the world around them. However, whereas earlier ubiquitous computing research focused on making these systems invisible and utilitarian, less has been said about the possibilities for weaving evocative and ambient interfaces for storytelling and narrative into our everyday experiences. This project specifically addressees new types of personalized, location- and context-specific interactive architectural experiences that emerge through the use of real-time environmental sensor and human data in conversation with one another over the lifetime of a building. This paper explores a design prototype entitled Place-based, Ubiquitous, Connected and Kinetic (PUCK) Experiences for Interactive Architecture.

Our current research projects and design prototypes focus on interactive architecture within the context of environmental media to enhance environmental awareness, augment presence in the physical environment, and enable participation in new ways of placemaking. Furthermore, this research investigates the idea of ambient storytelling [3], or how the built environment can act as a storytelling entity that engages and interacts with people in ambient and evocative ways. Within the PUCK application, development of personalized responsive and interactive environments arise as people spend time in and build a relationship with the spaces they inhabit habitually through a series of ongoing conversations between inhabitants and physical space.

With this in mind, PUCK reconsiders earlier notions of *genius loci,* specifically with regard to distinctions between space and place, and how the spirit of place was thought to take on a distinct character. As noted by Christian Norberg-Schulz [4], "...ancient man experienced his environment as consisting of definite character. In particular he recognized that it is of great importance to come to terms with the *genius* of the locality where his life takes place. In the past, survival depended on having a 'good' relationship to the place in a physical as well as a psychic sense." This focus on spaces having character and the importance of having a *good relationship* with places is an important underlying concept for exploring ambient storytelling and how building inhabitants can have meaningful, ongoing relationships with their buildings. Therefore, by integrating context-aware interactions with a building lifelog [5, 6] and access to backstory about an environment, ambient stories and characters emerge and present themselves through mobile and pervasive computing technologies, applications, and public displays.

This paper is organized as follows: in Section II, we discuss our overarching research approach to ambient storytelling and interactive architecture through the historical lens of lifelogging. In Section III, we describe the design prototype we designed for a newly built campus building. Section IV introduces the technical developments implemented in the PUCK prototype and the paper is concluded in Section V.

## II. APPROACH

Our approach focuses on the social and participatory elements of both ambient storytelling and interactive architecture. The research project described below uses a campus building as both a character and the setting for collaborative, context-specific storytelling in which the building inhabitants become an integral part of the story world. By inviting inhabitants to engage with both the building and their fellow inhabitants, we have introduced a new paradigm for place making within a playful, personalized, and interactive environment.

Research into lifelogging and backstory further provides a groundwork for thinking about new forms of storytelling. This has guided our research into how these stories could be customized and delivered in specific contexts and locations throughout the day, which we have termed Ambient Storytelling. This term is used to describe the context-specific and location-specific stories that emerge over time and immerse inhabitants in a story world through daily interactions with a building or architectural space. This form of storytelling within the built environment is enhanced through mutual participation and collaboration between inhabitants and the building as they begin to learn from and

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interact with one another over time. The development of a personalized responsive environment therefore evolves within the context of one's surroundings, creating a deeper connection and sense of presence within a specific location.

The practice of lifelogging, or documenting and broadcasting one's daily activities with wearable computing devices, has been a recurrent topic of our research. However, instead of people documenting their activities, we are focusing on designing lifelogs for the built environment. The notion of the lifelog has traditionally been tied to the idea of memory prosthesis for a single human participant or user. This coupling of the lifelog concept with a human participant has deep historical roots. In describing the MyLifeBits project, Jim Gemmell & Gordon Bell et al. [6, 7, 10] point consistently to Vannevar Bush's Memex system [8] as inspiration, and in particular they draw attention to the Memex as an indexing and recording system designed to augment a researcher's mental and physical experience. The centrality of a human user further embedded in Bush's description of an interconnected web of human knowledge (presaging the internet) that enables humans to share and navigate vast stores of information. But, while the imagined protagonist of Bush's tale is a human participant, our current media environment suggests a significant shift towards the recognition of non-human participants as authors and readers of sensor data in an emerging Internet of Things.

In more recent years, research focus has expanded beyond Bush's original emphasis on knowledge retrieval to subsume more experiential memory augmentation through video capture. However, this work largely retains the original assumption of an individual human participant. In the 1980s, Steve Mann began experimenting with streaming video and started recording his life using the Wearable Wireless Webcam in 1994 [11, 12]. Similarly, Bell integrated the SenseCam video recording system [12] into the MyLifeBits software. In both of these projects, the perspective of the video camera is aligned with that of a human participant observing their environment through a camera mounted to the chest or eye (a perspective that Mann has described as sousveillance [11]). However, recent research points to new perspectival orientations for lifelogging by using objects in the environment to capture video. For example, Lee et al. designed a lifelog system that captures images and other data from the perspective of objects (in proximity to humans) [10]. Nevertheless, previous research has yet to address interest in the possibility that objects and environments might themselves be positioned as the subjects of lifelogging.

Lifelogs for physical spaces therefore combines various building, environmental and human sensor data sets, as well as collaboratively-authored character development, to create an ongoing presence of a story. Through the integration of these various sensors and collaborative character development, the building itself offers a daily snapshot of both infrastructural behaviors, but also the behavior of the inhabitants of a building (movement through space, interests in context-specific information, time spent in the building). These elements, when combined, create the groundwork for ambient and persistent storytelling based on contextually relevant information collected and authored throughout the day.

For the purpose of our research, ambient storytelling takes place through the use of lifelogs, sensor networks and mobile devices within the built environment. By thinking more deeply about context and location specificity, we have experimented with what a lifelog for an architectural space might be and what backstories the objects within might contain, i.e., what a building would lifelog about, how it would communicate this lifelog to its inhabitants or to other buildings, what kinds of backstories the objects tell, and the stories that might emerge from this buildings' lifelog and backstories.

Finally, this model for ambient storytelling provides a platform for making sensor and environmental data more evocative and playful within the actual context of physical space and inhabitant activity. However, this engagement happens without explicitly revealing the data through a traditionally transparent information visualization model. Rather than simply visualizing the data that is produced and captured throughout the day, this information becomes a part of the story through ongoing conversations between a building and its inhabitants in which both learn from one another, further engaging an inhabitant in an ambient narrative experience. To demonstrate how ambient storytelling works within the built environment, we have developed a design prototype for PUCK: Place-based, Ubiquitous, Connected, and Kinetic Experiences for Interactive Architecture.

## III. PUCK Design Prototype

### A. *Overview*

PUCK explores the new conditions for interacting with architectural spaces and the kinds of evocative experiences and interfaces that emerge from these interactions. Ubiquitous and embedded technologies introduce scenarios in which objects, buildings and people produce an infinite amount of data and information, and are in constant communication with the Internet and with each other. Buildings have become dynamic, conversant entities that communicate directly with their inhabitants, objects, and other buildings through mobile devices, public displays, and ambient interfaces.

PUCK has been implemented within the School of Cinematic Arts Building (SCA) at USC as a test bed to explore the possibilities for new kinds of ambient characters, storytelling, and experiences of place to emerge within interactive environments. The SCA Building was chosen due to its new, state-of-the-art Building Information Modeling (BIM) and Building Management Systems (BMS), networks, and its unique context within the longstanding tradition of innovative storytelling at the School of Cinematic Arts. The SCA testbed contains over 4000 embedded sensors within its Building Management System, 60 WiFi access points, networked public displays, touch screens, near field communication nodes and approximately 2000 regular inhabitants populating it. For this case study, several design prototypes were implemented specifically for the SCA building. The following offers a description of how PUCK engages its inhabitants through mobile and ambient interfaces by describing how interactions progressively reveal themselves to building inhabitants through a mobile smartphone interface and various distributed environmental displays.

### B. *PUCK Mobile Application*

The PUCK mobile application (see Figure 1) provides a platform for building inhabitants to connect to all PUCK-enabled buildings, and for buildings to connect to individual inhabitants. After downloading the PUCK application to a mobile device, the user will be detected by the specific building she enters based on location sensors, GPS coordinates, or near-field communication technologies. Once a PUCK building has sensed a user and her mobile device's presence, the building will invite the inhabitant to add that specific building location to her application for further engagement and profile development. After an inhabitant has joined a building, she will receive notifications and prompts for action from a specific building, and will begin to develop an ongoing relationship with each individual building.

PUCK experiences are context- and location-specific, therefore, inhabitants can only access information about their relationship with a specific building when they are physically located in that building. After an inhabitant adds a specific building to her PUCK app, that building will recognize her every time she enters. This recognition plays an important part in the profile and relationship development for each specific inhabitant and building, and will impact how each building engages with its inhabitants.

When an inhabitant is detected by a specific building, that inhabitant is able to access information specific to the systems, networks, and experiences for the building she is in. Different aspects of each building will slowly reveal themselves to inhabitants as they spend more time in a building, providing a record of personal experiences with a building, as well as character traits for each unique building.


Figure 1: Puck mobile phone interface

### C. *Environmental Interfaces*

A PUCK building displays dynamic information about itself, as well as personalized information about its inhabitants based on various data points throughout the day. Visualizing the data produced by the systems embedded within buildings provides a new kind of narrative platform for telling stories about each building. This is the first point at which the character of each building is able to reveal itself, using its building system data within the context of specific physical space to communicate stories to its inhabitants. These stories emerge from fluctuations in data, often driven by changes in inhabitant behavior or system failures, and begin to make transparent the correlations between space, time and human impact throughout the day. However, the building data visualizations are not meant to be fully transparent to inhabitants, but rather draw them in to a rabbit hole of building data and systems through a somewhat mysterious public interface.

Therefore, to introduce inhabitants to all of their data-generating systems and sensors embedded within the walls, floors, and ceilings, PUCK buildings make themselves transparent through evocative data representations, revealing their inner complex systems and networks as dynamic stories of the life of the building. By drawing inhabitants into the data, PUCK buildings begin a conversation with their inhabitants about how a building responds to its inhabitants, presenting an image of how much energy and water is being consumed, fluctuations in temperature and carbon dioxide levels, wireless network activity throughout the building, and how inhabitants impact both the digital and physical landscape of buildings through their use of buildings. This point of entry into a deeper understanding of how inhabitants use buildings and how you as an inhabitant directly contribute to changes in these systems begins to reveals itself in a data visualization. Furthermore, each building uses Twitter to communicate real-time sensor data, network activity and the presence of specific inhabitants while providing context to each visualization.

Data Visualization and Twitter: Data generated by each building is presented to inhabitants in real time through a dynamic data visualization (see Figure 2). This data visualization provides a glimpse into daily building activity and is viewable on various displays within the common

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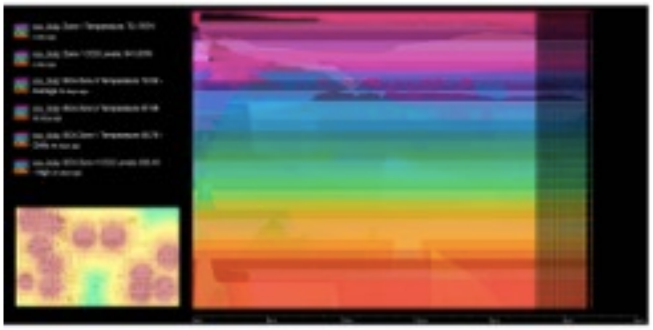

Figure 2. Public Data Visualizaion of Building Sensor Data

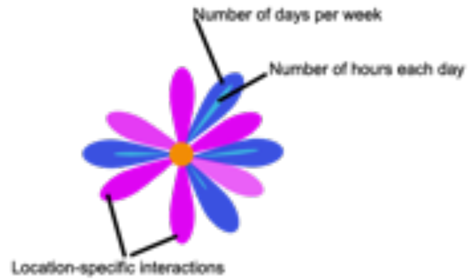


Figure 4. Personal Data Identicon

areas of buildings, as well as through the PUCK mobile application. This data visualization acts as the point of entry for inhabitants to engage with the building in a more meaningful way, revealing the life of the building that exists behind the walls, through its networks, and within the digital layer of the building. As inhabitants become aware of this secret life, they are invited to engage more deeply through personal interactions and conversations with the building.

To help inhabitants understand the various data points being used to generate the real-time data visualization, PUCK buildings use Twitter to tweet and display information about specific sensor readings, WiFi usage, and number of inhabitants in the building. Furthermore, inhabitants can follow each of their PUCK buildings on Twitter, contribute to a building's Twitter stream by sending messages as specific PUCK buildings, or by re-tweeting building information. Twitter also provides a social platform for buildings to reach out to their inhabitants and ask them to directly contribute information and media by engaging inhabitants in missions and other activities.

Personal Engagement with Buildings: After inhabitants are introduced to the kinds of stories the building tells through its data visualization and Twitter, the building will begin to directly engage specific inhabitants through visual and sonic interactions within the common spaces of the building (see Figures 3 and 4). By using the data a building is able to capture about an inhabitant through their mobile device, such as their presence in the building, the parts of the building they use most often, and the time of day they inhabit the building, a profile is developed by the building for each inhabitant. This is the first step towards the building becoming aware of and attentive towards its inhabitants.

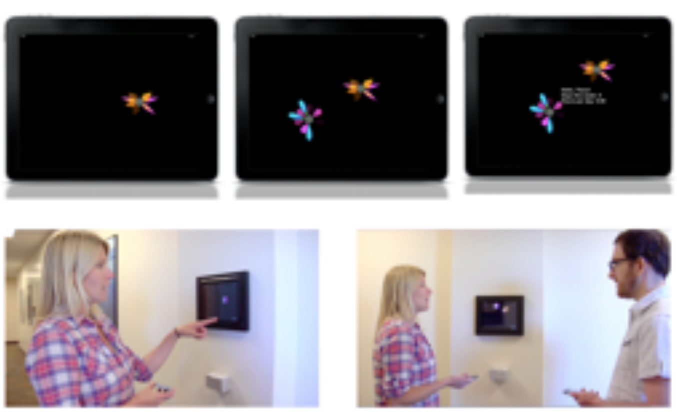

Figure 3. The building personally engages inhabitants through personalized data Identicons

PUCK generates a graphic identifier, or identicon, for each inhabitant based on a number of variables it learns about its inhabitants. This personal data identicon is an integral part of the relationship development process and is PUCK's way of showing an inhabitant that it knows she is present, that it recognizes the personal information shared with it, and that it wishes to engage an inhabitant directly. The parameters a PUCK building uses to generate a personal identicon is based on the context of each building, but includes data such as days per week a inhabitant has spent in a specific building, hours per day, or a tally of direct interactions an inhabitant has engaged in with a building, and the locations of the building most frequented.

These identicons are revealed to each inhabitant in various ways within PUCK buildings, appearing on public screens throughout each building, as well as within the PUCK mobile application. Inhabitants receive a new identicon each week, and are able to review all past identicons on their mobile device. This provides an overview of how one's relationship with each building is progressing, and also highlights milestones reached within an inhabitant's profile and relationship development with each building. Furthermore, these identicons develop different behaviors over time, based on how one's relationship develops, current data, and network conditions within the building.

### *D. Data Sculpture*

To communicate the significance of the process of relationship development, PUCK uses what it has collected about itself and its individual inhabitants to create a data sculpture to show its appreciation (see Figure 5). PUCK generates this data sculpture as a physical representation of digital information to show inhabitants what it has learned

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Figure 5. Personal Data Sculpture

about them, what they have learned about PUCK through their interactions, and how the two have worked together to establish a sense of place within SCA. This data sculpture is printed by PUCK into a tangible 3D object for an inhabitant after a number of milestones have been reached between the building and the inhabitant. Inhabitants are then lead to their personal data sculpture by following their identicon to a collection point within the building.

The personal data sculpture is generated using specific datasets and parameters to design an object that will always be unique to a specific inhabitant. These parameters are drawn from the data discussed above, including the overall building sensor data collected over a specified amount of time, each of the inhabitant's personal data sets, i.e., days of week spent in the building, number of hours each day, and milestones reached in their relationship development. The result is a generative model that is then printed using a 3D printer.

## IV. TECHNICAL IMPLEMENTATION

PUCK has been designed with a combination of off-the-shelf technologies, custom hardware and software, and open-source applications. Much of the off-the-shelf technology was creatively reappropriated to meet the needs of PUCK. The result is a unique set of technologies and interactive systems that has provided a preliminary framework for ongoing research into data collection and more robust indoor location tracking through wireless access point triangulation.

### A. Data Collection and Visualization

The data visualization is driven by real-time sensor data collected by the Building Management System (BMS), data tunneling OPC software, MySQL Database, Google App Engine (GAE), Python web services, and Processing.js.

To access building sensor data, the BMS data, i.e., temperature, $CO_2$, energy use, is tunneled from a facilities server and logged in a MySQL database on the virtual server. This allows us to format the data most usable for our purposes. Our virtual server then posts data from MySQL to the GAE data store through a web service interface. A Python web service was created to make a call to the data store to get a snapshot of the last update was from the MySQL database. This data is then reformatted into a Comma Separated Value (CSV) file, which was used to dynamically update the data visualization.

The Data Visualization is written using Processing.js visual programming language to be easily displayed on the web. This program looks for the updated CSV data from the Python web service, and updates with new data every 6 minutes as new data was generated, making the visualization dynamic through near real-time data. The CSV data is also archived so that a snapshot of 24 hours worth of data is viewable as data is generated and the visualization grows. Furthermore, the building Twitter feed was displayed along side the visualization, which would use the building sensor data being generated to send Twitter messages with sensor locations and current readings.

### B. Indoor Location Tracking and User Engagement

A number of options for passively tracking inhabitants were explored during the development of PUCK. Global Positioning System (GPS) technology was initially tested but was ruled out early due to lack of signal within the building, and also could not provide the level of data granularity for each inhabitant. Radio Frequency Identification (RFID) and other near field communication (NFC) technologies were explored but did not provide the passive collection of data.

In order to passively collect data that would be linked to each specific inhabitant, we looked for a technology that could be directly connected to a mobile phone so that data could be transmitted to a server and be linked to an inhabitant's device identification. We, therefore, explored the ANT+ protocol [13] for wireless sensor networks. The ANT+ protocol is most widely used in Heart Rate Monitors (HRM) and speed sensors for fitness monitoring and tracking. This protocol allowed us to use and modify off-the-shelf sensors and devices to accomplish the desired level of data collection related to a specific inhabitant, but also limited our options to using only the mobile phone for personal data collection in this iteration.

To determine an inhabitant's location using the ANT + wireless sensor network protocol, we designed location nodes that were distributed throughout the building. These nodes consisted of heart rate monitors connected to Arduino Mini microcontrollers and potentiometers, and were a creative hack that was necessitated by a technical hurdle. We discovered through the design process that heart rate monitors only transmit a signal after they have detected a user's heartbeat. Because we were not using the heart rate monitors for their intended purpose, which is to detect and monitor a human heartbeat, the heart rate monitors needed to be modified. We require the HRM's to constantly send out a radio signal that could be detected by the ANT+ sensor plugged into the mobile phone. To do this, the HRM's are connected to the Arduino Mini and a potentiometer to regulate the signal at a constant output. Each location node is assigned an ID number that corresponded to a location in the building. When the mobile phone sensor detects a signal from a location node, that location ID information is pushed to Google App Engine and we can then determine where in the building an inhabitant currently is.

The mobile application was developed to detect the specific building in which it is launched. The current application detects a specific radius around the GPS coordinates for the campus building. When the app is launched within those coordinates, it displays an inhabitant's personal statistics of use for that building. At the same time, the code that has been written to scan for the nearest three HRM radio frequencies runs in the background of the current interface application. As the phone scans and recognizes the nearest HRM's through the mobile phone ANT+ sensor, this information is updated in real time to Google App Engine throughout the day and will also procedurally generate the development of an inhabitant's Identicon within the application. Furthermore, because the scanning application looks for the nearest three HRM's, it can also determine which direction the inhabitant is moving in through triangulation.

A tablet application is also used to display real-time information and personal Identicons as each inhabitant navigates the building. The tablet app has been developed using the Unity game development tool so that we can create dynamic assets in real time to be displayed on the tablets. The location node information that is sent to Google App Engine from the mobile phone sensor informs the tablet application where an inhabitant is and displays his or her personal Identicon on the corresponding tablet, which is associated with a specific location node ID. This allows the personal Identicons to follow inhabitants as they move through the building with their mobile application launched. Furthermore, each Identicon is procedurally generated in Unity from the real time Google App Engine data so that the Identicon in constantly updated to reflect the data that the inhabitant is generating as he or she navigates the building.

## V. CONCLUSION

PUCK highlights important questions about how inhabitants come to understand and engage with ambient interfaces, ubiquitous computing systems, and context-specific interactions with the built environment. PUCK uses sensors, displays, and location to engage and teach inhabitants about the data being gathered on a daily basis. This data becomes a part of an emergent character of the building, in which stories emerge through data visualizations, personalized responses delivered to each inhabitant, and through data sculptures that tell the story of each inhabitants engagement with the building. This engagement with the system over time becomes a vital part of each inhabitant's personal profile and the relationship that emerges between the building and its inhabitants.

PUCK is meant to raise questions about how we think about and engage with the spaces that we inhabit, those that exist somewhere between being purely physical and somewhat digital. Lastly, PUCK brings to light concerns of privacy and surveillance by making the active profiling and data collection transparent, while engaging you in an active conversation about the future of interacting with environments that sense, generate data, and teach their inhabitants while simultaneously learning from them.

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