Demo: Creating Interactive Virtual Zones in Physical Space with Magnetic-Induction

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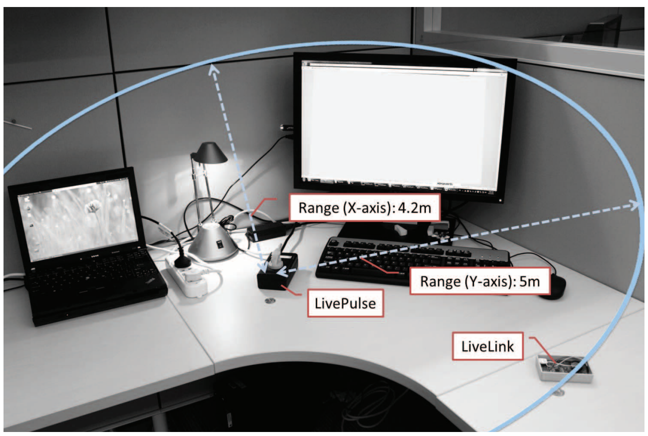

Figure 1. LivePulses project sharp and consistent "zones" around physical objects and spaces. LiveLinks interact with LivePulses to provide location information.

Abstract

In this demonstration, we present the architecture, implementation, and applications of LiveSynergy — a system that provides reliable proximity sensing and open interactive abstractions for physical spaces and objects, to enable rich interactions between humans and their environment.

Categories and Subject Descriptors

B.0 [**Hardware**]: General; B.4 [**Hardware**]: Input/Output & Data Communication; H.4.m [**Information Systems Applications**]: Miscellaneous

General Terms

Design, Experimentation, Measurement

Keywords

Localization, Magneto-Inductive, Tracking, Virtual Zone

1 Introduction

Discovering, identifying, and interacting with physical objects in our surroundings are fundamental for enabling a rich set of indoor applications. So is the capability for the environment to detect and adapt to the presence of humans.

There is a wide range of sensing technologies to detect relative proximity, including barcode, 2D-tags, RFID [1], ultrasound [2], wireless links, and computer vision. However, none of those approaches provide enough precision for our application in a cost effective and practical manner.

Figure 1 shows a virtual "zone" created by a LiveSynergy system. A typical system consists of three parts: *LivePulses*: These are devices that attach to physical objects to give them virtual zones. They detect when a human enters the zone. *LiveLinks*: These are mobile devices carried by humans to discover and interact with LivePulses. Mobile phones can potentially be used instead in the future. *An Interoperability Platform*: Wireless links and a set of IPv6-based open interfaces between LivePulses and LiveLinks that allow intuitive interaction between humans and the physical world. The basic proximity sensing modality in LiveSynergy is based on magnetic-induction, inspired by [3]. Magnetic coupling has the nice property of being isotropic in space. Humans, furniture, and most construction materials do not affect magnetic propagation pattern. Thus, the virtual zones created by LivePulses are much more clearly-defined and consistent than those using other technologies.

2 Architecture

LiveSynergy architecture has three components.

Indoor Proximity Sensing: All objects in the physical world occupy some tangible space. Interacting with an object can be represented as the event of entering its boundary. Consequently, accurately defining the zone of a physical object, and reliably triggering boundary crossing events are paramount. In our system, LivePulses are beacons co-located with physical objects to project signals that clearly define consistent zones. With LiveLinks, the mobile beacon receiver, we can reliably detect boundary crossing events.

Networking Backbone: The networking backbone links Live devices and back-end servers for delivering sensor data and invoking object APIs. We impose three requirements on the network. First, data reliability is crucial for manipulating the object states. Second, each Live device should have a

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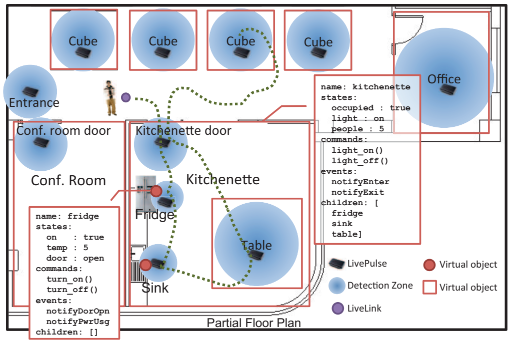

Figure 2. Physical objects occupy a zone. The states of zones are stored using a virtual object representation.

globally unique and addressable ID. Finally, as object interactions are real-time, the end-to-end latency should be low to improve the user experience.

Virtual Object Overlay: Physical objects have states. Objects offer APIs for manipulating their current states, and be able to react to state changes in other objects. We mirror the physical world in the virtual plane (on back-end servers) and provide object abstractions through *state*, *command*, and *event* APIs (c.f. Fig 2). This design enables an event-based programming model for users to add logic and intelligence among objects. The virtual plane preserves the hierarchical nature of the physical world with a tree structure.

3 Implementation

Virtual Zone: In our architecture, physical objects have clearly defined "zones" that are persistent over time. Humans entering this "zone" need to be detected accurately and reliably. Learning from the automotive industry and the beaver project [3], we build a magnetic field based localization system for enabling accurate and reliable indoor localization to fulfill the conditions above. In our system, a space (rooms, buildings, etc.) or a physical object (refrigerator, laptop, etc.) is instrumented with beacons at known locations, called LivePulse, that transmit dynamic magnetic fields. This field is modulated to encode an unique ID. The strength of the transmitted magnetic field can also be modulated to vary the diameter of the "zone" around physical devices. LiveLinks, equipped with sensors capable of receiving and demodulating the magnetic field, are used to detect entry and exit of objects' virtual zones. Humans carrying LiveLinks can therefore accurately localize themselves.

Networking: The network supports bi-directional traffic flows between sensors and back-end servers. Common traffic flows include upstream sensor data such as location updates and energy data, and downstream commands from the backend servers for querying and actuating sensors. In our implementation, we use 802.15.4c low-power radios, simple single-hop network topologies, and IPv6 all the way to the end nodes. 802.15.4c operates in the 779-787MHz band, which is less noisy compared to 2.4GHz, and has greater penetration and range indoors. Our system maintains a one-hop network between sensing nodes and gateways, allowing sensing nodes to be smaller and cheaper.

Virtual Object Abstraction: In our architectures, physical spaces and objects are organized hierarchically and are

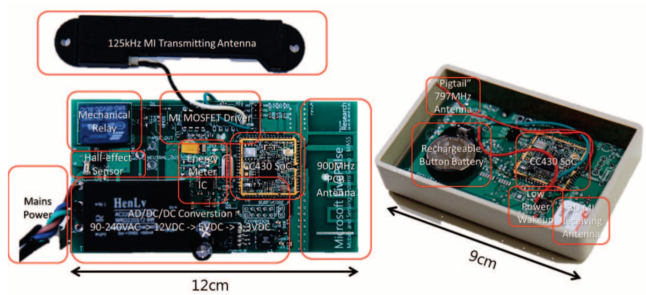

Figure 3. LivePulse (left) and LiveLink (right)

event-based. We represent them uniformly with four elements - *states*, *commands*, *events*, and *children*. States refer to some current property of the physical object or space. For example, a refrigerator's states could include "on_off" and "internal_temp". States are similar to class variables in Java. Commands are actions that the object/space can perform, such as "turn_on". Commands are like methods in Java. Events represent a way for physical devices to actively "reach out" to us. Users or objects can "subscribe" to an object's event (by registering its own IP address in that object's events table). An useful event for a room could be "notify_if_X_enters". When it is triggered, a message is sent to that IP. We choose to use JSON as the data format and HTTP/REST as the interchange protocol for interoperability.

4 Demo Description

We plan to instrument LivePulses under every demo booth a priori. During the demo session, we will distribute LiveLinks to interested visitors as they enter the demo area. The LiveLink carried by each visitor, combined with their mobile phone, functions as a guide, which will localize the visitor, deliver useful information and provide guidance. When entering the zone of a specific demo exhibition, the user will be notified via an SMS containing information of the project, and a URI to our mobile web portal. From this portal, the visitor can obtain more details of the current demo and locations of nearby demos. In addition, users can "vote" for the projects they like, simplifying the voting process. The amount of time each visitor spends in front of a particular booth and energy usages of every booth are recorded as well. Such information is displayed at our booth and can aid in selecting the "best demo". At our demo booth, visitors can interact with several appliances and objects in interesting ways using LivePulses and LiveLinks. Using a simple yet expressive authoring tool that links object commands with events, visitors will be able to easily build their own LiveSynergy applications and program the physical world.

5 References

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