The Intuitive Control of Smart Home and Office Environments

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Abstract

Along with the associated film, this paper presents an approach to individually controlling home and office fixtures such as lights, window blinds, cooling and ventilation units with an 'intuitive gesture-based controller' using a smart phone. The implementation of the gesture controls is based on the magnetometer, gyroscope and accelerometer built into the most recent smart phones. The user simply points to target objects and completes specific gestures. For example, pointing to the top of a window and completing a "down"-gesture is interpreted as a command to lower the blinds at the window. Pointing the device to a light fixture and doing an "up"-gesture raises the light levels. In combination with addressable fixtures and wireless infrastructures, this phone controller reveals how a wide variety of fixtures in a building can be intuitively controlled by pointing, using only a single button and gesturing.

Categories and Subject Descriptors H.1.2 [**Models and Principles**]: User/Machine Systems.

General Terms Human Factors, Documentation

Keywords Smart Home, Intuitive Control, Gesture-based, Individual Controls, Smart Offices

1. Problem statement

Building lighting fixtures and room conditioning units have been automated to a certain extent using intelligent control strategies, e.g. occupancy sensing and daylight harvesting in order to save energy. Typically, these controls are centralized and often block individual input. Involving the users by giving them complementary personal control is crucial for the acceptance of intelligent control strategies, for sustained energy efficiency, and for providing comfort and well-being for building occupants. In a building with many different fixtures such as lights, window blinds, heating-, ventilation- and air conditioning units, the visualization of control mechanisms is a challenge. Particularly, as the number of target devices increases, the correspondence between functions and buttons will become more complicated and the user's cognitive load is increased unacceptably [1]. Although the more typical floor plans may be an appropriate way to provide an overview of the building status, it may not be the most effective way for non-architects to control nearby objects. As an alternative, some research on voice control of home appliance has been conducted [2] [3]. However, it is not simple to express spatial information (which blind, which light fixture, which diffuser) easily in natural language. In the meantime, the uses of smart phones have rapidly extended to daily life and offer new technological possibilities.

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2. Concept

The concept of an intuitive controller approaches these issues with a technique whereby individuals use their own phones to point to fixtures and complete gestures to control them. The user selects a specific fixture by pointing the phone towards it. A single button and an optional up/down-gesture with the phone then controls the selected fixture. As a result, the user's attention does not need to be focused on the control interface but actually remains in the real world. The experimental tests that are shown in the 'intuitive control' film provide additional indications that point-and-gesture movements are a natural behavior. In these tests, individuals were asked how they would perform specific tasks such as turning off a light and opening window blinds using a wand. The wand has been used as a synonym for the most intuitive control device. The experiment showed that nine out of ten individuals used pointing and gesturing to manipulate the fixtures.

The overall project implies affords in both, software engineering and usability engineering. Software engineering challenges include questions about how to deal with multiple control vendors for different fixtures and how clients and services can be decoupled. Usability challenges include the overall question of how an intuitive control mechanism can be found and how it may look like. Having proposed a human-machine interface, there are related questions to that

specific interface, including how to deal with error rates from sensors, how to prevent and recover from errors and how to identify objects behind each other

To address the challenges of multiple fixtures that can be controlled with multiple control vendors, the 'intuitive control' film demonstrates the use of a personal smart phone as a controller with a number of different fixtures and also presents several implemented HMI concepts.

3. Scenarios

The proposed solution can be applied in different scenarios. Our prototype has been implemented at an office environment with the objective to support energy savings and personal well-being of the occupants. However, the system can be used easily in other scenarios such as smart homes (the phone as remote control for home appliances and fixtures) and as a support for disabled people. For instance, hotel visitors might also use the system to control fixtures in a hotel room after being granted access from the administration. This selection represents only a small number of possible scenarios.

4. Realization

The 'intuitive controller' is realized using the smart phone's built-in gyroscope, magnetometer, accelerometer and WiFi localization within the building. While the smart phone's sensors identify the direction of the device, a WiFi fingerprinting technique provides the location in the building with room-accuracy. The fixtures with their internal addresses are configured on a server in the background. The position of the fixture in the room is then added by simply pointing the phone to the fixture. When the user wishes to control a fixture, the device compares the current position (the pitch and yaw angles of the phone's direction), with the recorded positions of all fixtures in that specific room, and selects the most appropriate.

The server also acts as a broker, intermediating between the phones (clients) and the fixtures (services). This decouples the clients from specific building protocols such as BACnet and OPC. Since many buildings already have WiFi access points, no additional infrastructure is required to realize this control mechanism as long as the fixtures to be controlled are addressable.

5. Prototypical implementation

This project has been implemented in a prototype at the Robert L. Preger Intelligent Workplace (IW) at Carnegie Mellon University. Housing the School of Architecture's Center for Building Performance and Diagnostics, the IW incorporates a number of architectural features that provide for the health, productivity, and comfort of its occupants and the sustainability of its construction and operation. As a living laboratory where new technologies can be tested easily, the IW has a number of addressable fixtures for lighting and thermal conditioning, and as such is a very convenient place for this 'intuitive control' experimentation. The system is currently in a broader field-test by the occupants of the IW with seven resident iPhone devices.

6. Benefits

Recent development in smart home and smart office controls tends to lock the occupant out of the system on the assumption that they will make errors or lose interest in the task of controlling their environment. This research assumes that providing control to the user is crucial to comfort, well being and energy efficiency. However, this control must be simple, fast and natural.

This 'intuitive control' proposal is a promising concept for controlling fixtures of buildings with personal phones using the idioms of Ubiquitous Computing. Compared to other gesture-based control interfaces, the advantage of this proposal is the closeness to productive use since no special infrastructure is required. Smart phones, WiFi access points and addressable fixtures are already available in many commercial buildings. Having this infrastructure in place, the proposed intuitive control system has been developed to require only software installation and provides instant gratification for the occupants of todays homes and offices.

7. Future Work

The phone is currently not positioned within the room since GPS is not available in buildings and the WiFi fingerprinting only provides room accuracy. If a real WiFi triangulation with more advanced smart phone devices could be realized, the direction of the phone could be combined with its exact three-dimensional location in the room. This would make the current system more accurate although in our test environment, an exact positioning is not necessarily required for rather small spaces with an average of five addressable fixtures per room.

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