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# Introducing Personal Operating Spaces for Ubiquitous Computing Environments

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## ABSTRACT

Within a ubiquitous computing environment, a user will own and make use of many devices that vary in functionality and power. Furthermore, these devices will most likely be interconnected around a space, such as a room in an intelligent building or a public space. Devices may join and leave the space through device detection and location management techniques in an ad-hoc seamless manner. For example, a user's home space may automatically detect and add a personal smart phone device, which could then be used to interact with other devices within the space. This study is concerned with the concept of a personal operating space: an entity formed for interaction between a user's mobile device and any environmental devices/services in the local space.

## 1. INTRODUCTION

To coincide with the vision of pervasive computing, everyday computing spaces will need to become part of the users background environment, and gradually become more ubiquitous in nature. Ubiquitous spaces will allow users to seamlessly access and use applications across the myriad of devices provided by each space. Achieving this level of seamlessness requires true interoperability across heterogeneous devices, networks and applications. Much of this work is being lead by standards bodies such as the IEEE, OMG, W3C and the UPnP foundation, which all recommend their own standards for addressing interoperable components needed in intelligent building environments. Examples include bluetooth for personal area radio communication, TCP/IP for network communication; object and service orientated middle-ware technologies, such as CORBA and Web Services, and UPnP for communication between everyday devices in buildings. Additionally, methods for semantic interoperability are being realised by the introduction of semantic web technologies for terminology definition and mapping. Services can then use a shared ontology to develop methods for interoperation during spontaneous interactions (OWL-S). All of these technology are well known for forming an integral part of any ubiquitous computing environment, with the challenge being to combine these to offer new types of behavior; characterized by being considerably more powerful and seamless than services today.

Today, people tend to make use of different spaces over time, with each space differing depending on person, group or context (such as rooms in a building). People are also visiting foreign environments, such as buildings that offer a range of services from Internet access through to heating and light control. Furthermore, these nomads are increasingly carrying mobile devices, the most common being smart phones, which are essentially treated as personal devices, with the same ubiquitous interfaces when mobile. So why not treat these ubiquitous personal devices as a mechanism for interacting with and configuring, in a personalised manner, foreign or home environments? Therefore creating a personal operating space between a user's personal devices and any shared devices within the local environment. This is the question this study seeks to address by building on theory from both nomadic computing [4] and ambient intelligence [1], and applying this in the context of ubiquitous computing, hence turning to invisibility and smart spaces as the main criterion for success.

## 2. SCENARIOS

A few scenarios should help to narrow down the concept of a personal operating space:

### 2.1 Hotel Room

Bob arrives at his hotel room after a long tiresome journey. As Bob enters his room, a symbol on Bob's phone starts to flash in an unobtrusive manner. Bob now knows he is within a 'smart space', and decides to read his RSS based News Headlines. Using his phone, Bob selects the smart space menu, which has now become 'active' by the phone implicitly merging itself into the space. After an authentication procedure between Bob's smart phone and the smart space, Bob is presented with two menus: personal space and control space. Control space gives Bob the capability to 'control' his current environment (such as lighting and temperature etc), therefore using his personal phone as a universal remote control device. Personal space allows Bob to import his personal preferences into the current smart space, thus personalising the set of services offered by the space. Bob hits the personal space menu on his phone causing the smart space to present Bob with a set of application services available within the current space. Each application service is abstracted into 'tasks', such as 'Email', 'News', 'Music Streams', 'Clipboard' etc. Bob selects the 'News' menu, which causes the smart space to invoke an application that can handle RSS News feeds. When booting the application, the smart space configures the application to use Bob's preferences, thus retrieving Bob's personal selection of NEWS feeds and blogs. The application's display output is piped to a high resolution screen within the room. In the case of multiple screens being present within the space, Bob may simple choose to teleport the display to an alternative screen, which could be present within the sleeping area for instance. Again, with his smart phone as a remote control, Bob navigates over the various NEWS feeds.

Whilst reading his set of web feeds, Bob gets irritated with the temperature in the room. Instead of fiddling with the thermostat, Bob opens the 'Control Space' menu using his phone, and then clicks on the temperature menu. Using this standardized menu, Bob alters the room temperature using the joystick control on his phone.

After checking out of the hotel, Bob's personal agent confirms that all personal preferences have been removed from the visited smart space.

## 2.2 Conference Lecture

Jane will be giving a guest lecture at a distant university. Before leaving, Jane adds her presentation to her personal space by 'edit/copying' the presentation and notes to her pervasive clipboard. For backup purposes, Jane's presentation and notes are also sent to a flash disk or personal server, which Jane usually carries.

After arriving at the lecture hall, Jane checks the Smart Space menu for the various services the space provides. Selecting the Smart Space menu causes an authentication procedure to be performed between Jane's phone and the smart space. Jane then selects the 'Control Space' menu and determines that the lights, temperature, projector and conference computer may all be controlled. Jane uses her phone to power up the projector by clicking 'start projector'. Having started the projector, Jane selects the 'Personal Space' menu thus causing the smart space to present Jane with the various application services within the space. Jane then clicks on pervasive clipboard, which displays the presentation/notes that were copied over earlier. Clicking on the presentation causes the smart space to import the presentation to the projector computer, which then triggers an appropriate application that can handle the presentation format, hence projecting Jane's presentation. Application control is then passed onto Jane's phone, allowing Jane to move through the presentation by pressing various buttons on her phone.

At the start of the presentation, Jane once again invokes the 'Control Space' menu to dim the hall's lights. When leaving the lecture hall, Jane's personal agent removes the presentation from the visited smart space.

# 3. SMART PHONE INTERACTION IN INTELLIGENT BUILDINGS

Although one of the main visions of ambient intelligence is to provide 'super smart environments' that anticipate and fulfill our everyday needs autonomously, a 'manual' or 'override' method of control will be a much requested feature; especially in foreign environments where previously learnt knowledge is inapplicable; but also in the case of uncertain events an environment has not anticipated. This leads to two complementary strands of ambient intelligence: AI controlled buildings and human controlled buildings. AI controlled buildings will execute actions specified by intelligent agents, while human controlled buildings will execute actions specified by users. Human controlled buildings will have intelligence however, but not to the extent of AI controlled buildings. For example, a user could request the environment to "display email", which would lead to the user's email being displayed on a screen "situated near" the user. Additionally, these two techniques could be combined, hence complementing each other. For example, a user could request the heating to be 'turned on', which may cause the building to adjust the room's temperature according to the user's preferences. These preferences could be derived from inferences made by intelligent agents and accessed by using a personal mobile device as a form of identity.

Currently, we are examining the concept of personalising spaces by treating a user's smart phone as an identity, which is linked to a network profile holding a user's preferences, e.g. a list of RSS subscriptions. Our aim is to combine as much of this profile as is needed, into the user's current space, by considering any constraints associated with the space, e.g. matching a user's preferences with a set of services offered by a hotel room. We are also looking at infrastructures that allow mobile devices to seamlessly become part of spaces within intelligent buildings, and subsequently control any devices and services offered by a space. Figure 1 details a high level architecture, illustrating part of our personal operating space infrastructure, which allows mobile devices to combine with the local space, and invoke any services offered. Each component has been briefly described below:

## 3.1 Mobile Device Mediator

As mobile devices enter a particular space, the mobile device mediator (MDM) performs server beaconing via one of its sensors, therefore detecting any mobile devices within the current space. Our current prototype employs the now pervasive bluetooth technology for device detection and communication between a smart phone and MDM. Other wireless technologies may be used depending on granularity of a space. For example, one may wish to split a room into lots of mini -spaces by using sensing technology such as RF-ID. Alternatively, a space could span the whole building, therefore using WiFi technology. We believe bluetooth provides an ideal technology for defining the boundary of a space, since the range of bluetooth suffices for room based interaction; hence aligning with the theory of our behaviour being associated with the room that we are in, and thus so our control needs [1].

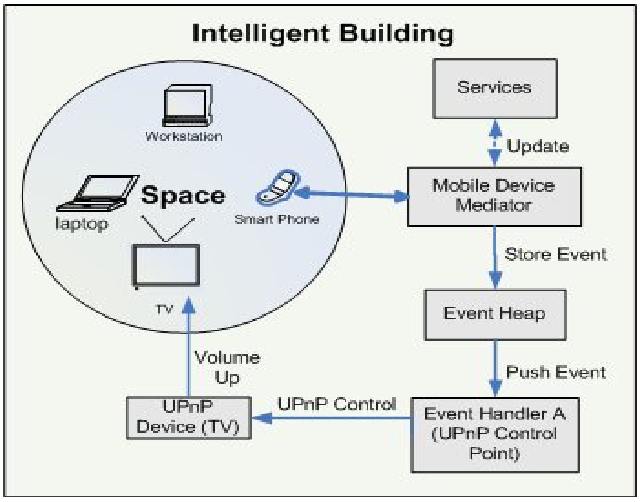


**Figure 1:** *Using a smart phone to interact with a space in an intelligent building*


**Figure 2:** *Interacting with the IIE space using a smart phone*

The main role of the MDM is-to authenticate mobile devices appearing in the space, and mediate service events between mobile devices and any devices/services within the building. Once a mobile device has authenticated itself to the space, the MDM invokes the services component to gather a list of services in the current space. This list is then translated into a form interpretable by the mobile device, and then transferred to the phone. Our current prototype uses a low-level feature associated with Sony Ericsson phones, for the installation of temporary hierarchical menus over bluetooth RFComm channels. We believe this approach demonstrates a key point in that users with SE phones need not install any software on their mobile devices to interact with a space. This essentially makes the whole process much more invisible. Embedding this same feature in the operating systems of other mobile devices, would essentially allow nomads to interact with smart space environments in a seamless manner.

Intelligent buildings will typically have one MDM per room, which depending on sensor granularity, could serve multiple spaces.

Figure 2 (going from left to right and top to bottom) shows the installation of a group services offered by the IIE space (intelligent inhabited environments room). As shown, the 'IIE space' has a menu for invoking the 'control space' of the room, together with various services such as 'NEWS' and 'Notice-board'. Once the control space menu is hit, the user is made aware of the fact that lighting may be controlled. Using the phone, the user may select the lighting menu, and subsequently select the 'switch on' menu. This will then fire an event to the MDM, which will pass the event to the event heap causing event notification to a specific handler (a UPnP control point) therefore turning the lights on. After becoming aware of services within a space, a smart phone may issue various commands that are passed from the phone to the MDM, which then relays commands to the event heap.

## 3.2 Event Heap and Event Handlers

The event heap model [3] is based on the concept of tuple spaces, and allows for decoupled, spontaneous and flexible interaction amongst services, making it ideal for nomadic interaction within smart spaces. Applications need not 'rendezvous' to communicate, but communicate indirectly by understanding the same event types; since reading, monitoring and restoring tuples can cause applications to perform appropriate actions. Events from the MDM are sent to the heap, which then matches the event type, maybe using fuzzy reasoning, to an appropriate event handler. Once a suitable handler has been found, the event is passed to the chosen handler and processed accordingly. Event handlers express interest in events by subscribing to events published by the services component. Sometimes, more than one handler may be required to process an event. In this case, the event heap will take the 'service description' associated with the relevant event, and compose a workflow between handlers. E.g. Use a 'NEWS Handler' to find an appropriate RSS reader application; use the 'Location Handler' to find a display situated near a user in the space; use a 'Display Handler' to output NEWS to the chosen display.

Intelligent buildings will generally have one event heap per building. However, separate event heaps could be available in every room to handle load balancing and scalability. Communication between heaps could be conducted using peer to peer techniques.

### 3.3 Services

All services available in a space are handled by the services component. This component includes semantic descriptions of various services, therefore allowing composition of services into complex work-flows. It also includes information about how these services are presented to a phone: figure 3 shows an XML representation of services, which are used to generate a set of hierarchical interfaces for display on mobile devices - notice that this set of services was used for generating menus for figure 2. Studying the XML, 'menu' tags correspond to hierarchical menu based organisation of services; 'triggertask' tags correspond to actual events that are sent from a smart phone to MDM and then to the event heap. The XML 'task' attributes within 'triggertask' tags are used by the event heap to find a relevant event handler. E.g. the task 'http://essex.ac.uk/idorm#LightOn' will be passed to a UPnP device handler. Note that the task 'http://essex.ac.uk/idorm#LightOn' could point to a semantic service description, represented in a language such as OWL-S. Depending on device capabilities, richer XML interface languages, such as XAML, may be used to present services to devices.

```
<menu label="IIE Room">
    <menu label = "Control Space">
        <menu label = "Lighting">
          <triggertask label="Switch On" task="http://essex.ac.uk/idorm#LightOn"
          oncomplete="Let there be light"/> </menu>
    </menu>

    <menu label = "Personal Space">
        <triggertask label="News" task="http://essex.ac.uk/idorm#NEWS"/> </menu>

    <menu label = "NoticeBoard">
      <triggertask label="Add Note" task="http://essex.ac.uk/idorm#ADDNOTE"
        oncomplete="Enter NOTE on Board"/> </menu>
</menu>
```

**Figure 3:** *Describing a list of services for presentation to a mobile device in the IIE space*

## 4. DISCUSSION: PERSONAL OPERATING SPACE (POS)

Considering the scenarios and high level frameworks, we can determine that a personal operating space will consist of a 'Control Space' and a 'Personal Space'. The challenge therefore lys in realising both of these, together with their underlying support infrastructure. An account of each POS component, and its significance, has been summarised below:

- Personal Space. Today, most personalised computing environments tend to be fixed to a certain space. For example, a work based computing environment is typically accessed from a particular computer or network at work. Although applications/protocols do exist for allowing remote access to resources; for the lay person, these require considerable computing knowledge therefore being deployed by a small minority of users such as systems administrators and tech savvy users (even then a hideous amount of configuration is required). A personal space is a logical entity, which does not necessarily reside on a personal device of any sort but is present in the network everywhere. For example, a user may enter an environment, and 'seamlessly' summon his or her personal environment using an appropriate device. Environments could be presented depending on context or manually selected by the user. This study is concerned with using the now pervasive mobile phone as a way to convey 'identity' to import a user's environment into a space, hence transforming a space into a user's personal space.
- Control Space. Our environments are becoming increasingly augmented with devices of various shapes and sizes. Controlling these devices, especially in densely populated device areas, can often be an overwhelming task - just ask lecturers about lighting and projector control in lecture theaters. Lecturers do however carry mobile phones, and are more than likely to be familiar with these devices and their respective interfaces. Control space is therefore concerned with controlling everyday environments such as rooms, using mobile devices that we are familiar with.

Here at the University of Essex, we are examining the concept of a personal operating space, by considering the use of smart phone devices for personalization of end user services, together with control of devices within our UPnP based intelligent building [2]. We have defined sample architectures, and are currently building concept demonstrators for evaluation.

## 5. REFERENCES


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