Introducing Personal Operating Spaces for Ubiquitous Computing Environments

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ABSTRACT
Pervasive computing environments will combine everyday physical spaces with network aware devices and services; hence providing computing behaviour that is much more entwined with the environments we inhabit. Within such environments, a nomadic user will own and make use of many services attached to, and organised around, physical space. This study introduces the concept of a personal operating space: an entity formed for personalisation of space specific services, by treating a user's personal mobile device as an identity for personalisation.

1. INTRODUCTION
Pervasive computing causes us to examine ways in which existing computing infrastructures combine with everyday physical and environmental spaces; by understanding the dynamics of device rich environments; how devices are networked to correspond to the boundaries of physical space; and how users generally interact within and across these spaces: commonly referred to as 'smart space environments'. To coincide with the vision of pervasive computing, smart spaces will need to become part of the users background environment, and gradually become more ubiquitous in nature. These spaces will allow users to seamlessly access and use services 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 smart space 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 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.

At the University of Essex, we are examining ways in which people interact with everyday spaces such as intelligent buildings. 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 application based services, such as media applications, through to heating and light control. Furthermore, these nomads are increasingly carrying mobile devices, the most common being smart phones, which are essentially being treated as personal devices. The aim of this work is to treat these ubiquitous personal devices as a mechanism for interacting with and configuring, in a personalised manner, pervasive computing spaces; therefore creating a personal operating space between a user's personal devices and any services within the local space. A personal operating space will allow a user to both import a personal environment into the current space, along with personalising any services and devices provided by the space. This study seeks to build on theory from both nomadic computing [7] and ambient intelligence [9], and apply this in the context of ubiquitous computing; hence turning to invisibility and smart spaces as the main criterion for success.

2. SCENARIO
The following scenario should help crystallise the notion 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 standardised 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.

3. PERSONAL OPERATING SPACE

Currently, we are examining the concept of personalising space based media services 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 media 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 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 is the best of the current RF technologies for defining the boundary of a room based space; hence aligning with the theory of our behaviour being associated with the room that we are in, and thus so our control needs [9].

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 context model 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 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 personal operating space, causing event notification to a specific handler (a UPnP control point) and 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 personal operating space.

3.2 Context Model

Services in a space are handled by the context model component, which is divided into the virtual services and space map sub-components:

The virtual services component provides semantic descriptions of services discovered within a building. Semantic descriptions allow composition of services into complex workflows, together with providing information about how these services may be presented to a space as 'Tasks': figure 3

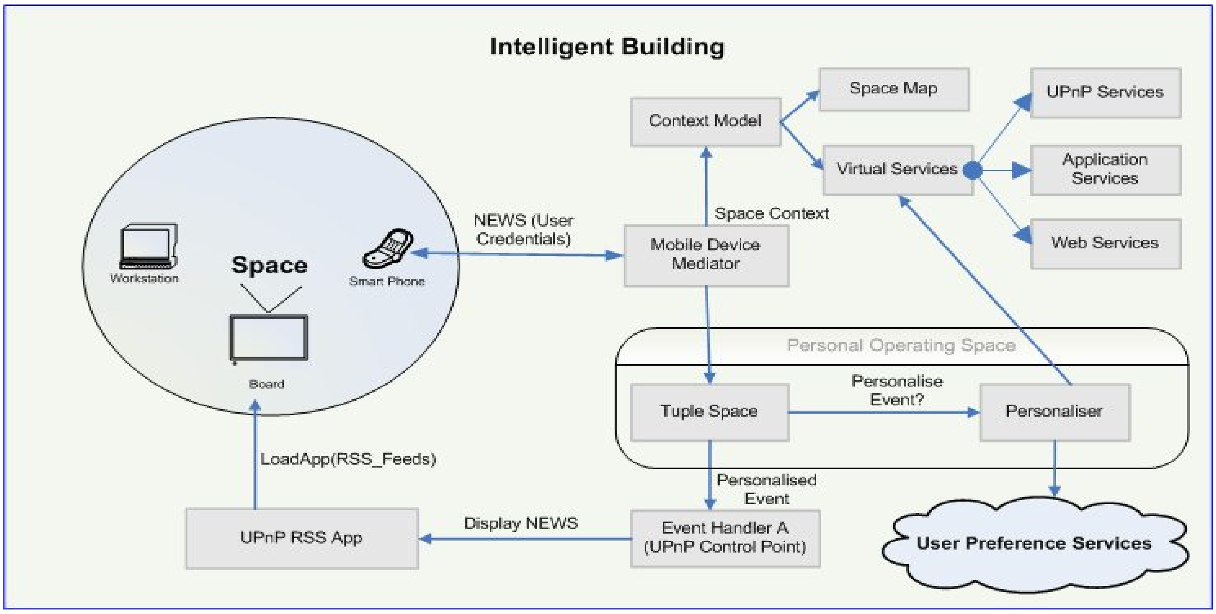

Figure 1: *Using a smart phone to interact with a space in an intelligent building*

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 personal operating space. The XML 'task' attributes within 'triggertask' tags are used by the personal operating space to find a relevant event handler, e.g. the task 'http://essex.ac.uk/idorm#LightOn' will be passed to a UPnP device handler. We are currently using OWL-S to describe services. Depending on device capabilities, richer XML interface languages, such as XAML, may be used to present services to devices by transforming service descriptions (as in figure 2) to an appropriate display language.

The space map groups virtual services according to user defined notions of space. Here we intend to use techniques similar to Activity Zones [8], where building based regions are created from observed user behaviours such as movement, position and shape. Various techniques are then used to build a volume model of a person's trajectory in a space, using stereo computer vision. An activity map is then generated from this volume model. The map groups various sections of a physical space into areas of activity, which are updated with real-time information regarding users and other contextual information. Applications may then use the activity map to make decisions based on rich context models. A personal operating space will require a person specific-region centric view of space, to decide which devices and services to personalise, with regard to the device space surrounding a user.

3.3 Personal operating space and event handlers

The personal operating space is essentially divided into two components: the tuple space and the personaliser. The tuple space in this context is a network aware, event heap model [5] and allows for de-coupled, 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. The personaliser component is used to personalise any services in the space. It works by using dynamic filtering processes to find relevant preferences for use with relevant virtual services.

Events from the MDM are sent to the personal operating space, which then attempts to personalise these events before dispatching them 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 context model component.

4. RELATED WORK

Over the last few years, much work has been conducted in pervasive computing to bridge the physical and virtual worlds. The Cool-town project [6] is one such example, where things are given web presence by assigning URLs to everyday objects. Infra-red beacons are used to seamlessly send URLs to mobile devices, which then invoke these URLs to request an appropriate web page. We believe this approach is very well suited to assigning 'web information' to 'physical' things. However, some 'services' in a ubiquitous computing environment will not necessarily be identifiable through a tagging system or a formed based web page.

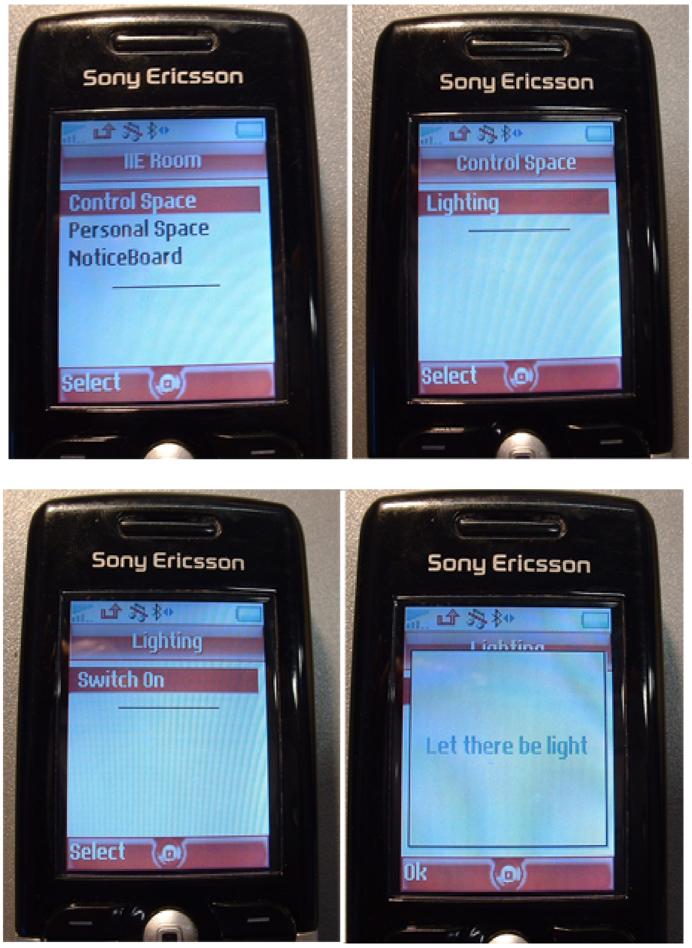

Figure 2: *Interacting with the IIE space using a smart phone*

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<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*

For example, many intelligent building environments include services made available through middle-ware such as UPnP, Jini and other service discovery frameworks. Cool-town fails to address this by suggesting that web-pages be provided to interact with any service within a space. Doing this fails to address the benefits that certain, pervasive computing middle-ware technologies provide [4]. Our approach aims to support any type of pervasive middle-ware technology, by wrapping existing environmental services into virtual services using semantic web techniques. This way, the structure of the web is still utilised without removing support for any service specific middle-ware technology.

In terms of interaction, the context model represents space specific services in a hierarchical, task-driven manner. Recent studies have shown that a majority of mobile phone users now group and organise functions in a hierarchical manner [2]. This is quite different from the Cool-town URL approach, where URLs are displayed on a PDA with no contextual organisation. Our current MDM works by sending a hierarchical representation of services (figure 3) within a bluetooth defined space, for display to a mobile phone device. The MDM component can handle asynchronous events, therefore allowing environmental services to send various alerts/notifications to a mobile phone device. Finally, interacting with things in a space may require more varied and coarser levels of granularity; rather than pointing to or touching things. We are particularly interested in using short-range omnidirectional beaconing, such as bluetooth, rather than unidirectional technologies as deployed in Cool-town. We think that both types of beaconing granularity will be complementary, and suited to specific scenarios in pervasive computing spaces.

Another nomadic system is the Meeting machine [1], which embraces both nomadic computing and infrastructure-rich interactive workspaces. Here, interactive workspaces allow information to be shared within meetings. The Cool-town system [6] is used to provide nomadic access to the interactive workspace device. A remote control device is used to load files into a shared space, the e-table. We believe our mobile device mediator could be used to establish and coordinate multiple connections from users' personal devices (phones are starting to store huge files) to space specific services. This would provide users with another interaction mechanism for interactive workspaces. Generally, the personal operating space is primarily concerned with personalising a nomad's current space, whereas the meeting machine is concerned with allowing nomads to seamlessly share information in a collaborative setting.

Overall, the big differentiator between a personal operating space (POS), and related work, is the ability to personalise information and device based services within a user's current space. For example, the POS could be combined to personalise existing nomadic infrastructures, such as cool-town, through the filtering of space specific URLs based on a user's profile.

5. DISCUSSION

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 lies 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 personalisation of end user services, together with control of devices within our UPnP based intelligent building [3]. We have defined sample architectures, and are currently building concept demonstrators for evaluation.

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