proXimity: Ad-Hoc Networks for Enhanced Mobility

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Abstract. David tries not to use unfamiliar trains and buses, he doesn't travel to places he doesn't know, and he doesn't travel in unusual environments without a companion. David is visually impaired and in such cases he becomes disoriented from a lack of preview, knowledge of the environment, and orientation information and is consequently without the foundations on which to base mobility decisions. While his experiences are not always true for all visually impaired travellers they do represent the majority experience of David's peer user group. proXimity is our attempt to address David's travel problems and is based on our previous work in Hypermedia and Real-World Mobility. By using combined Hypertext and mobility paradigms we move toward a system that will assist David in his travels. The primary goal of proXimity is to augment David's reality by giving hypertext a physical presence in the real world. We analogise the real and virtual, and so aim to provide Nodes (link targets), Links, and Anchors in the real world. Therefore, hypertext information that describes a physical location also has a physical presence and 'local' physical artifacts can be augmented by 'remote' hypertext and semantic information.

1 Introduction

We are concerned with the mobility of visually impaired travellers in complex and unfamiliar internal and urban environments. Visually impaired travellers become disoriented in these environments and this is especially the case when airports, bus or train stations, shopping centres, and unfamiliar cities are to be traversed. In such cases the traveller is left without the foundations on which to base mobility decisions due to a lack of information about the environment. However, their journey can be assisted by supplying this 'lost' information and we envisage (and have started to develop) a system that adapts to an individual based on their planned and completed journey, their mobility requirement, and the environment being traversed.

proXimity is our solution to the travel problems of visually impaired pedestrians. proXimity tries to extend the link metaphor from hypermedia into the real world. We try to link the real and virtual so that visually impaired users can access complex travel scenarios and locate physical objects in the real world by links pointed to them in the accessible virtual world.

We perceive inadequacies in the way the real and virtual worlds currently blend, and are particularly concerned by:

1. The presumption that ambient devices will always be statically networked either by wire or by wireless means.
2. The conventional wisdom which sites the user-interface (Siren) with the device (Fire Alarm) thereby enforcing a designers view of an individual.
3. The missed opportunity to use an ambient device designed for a specific task (marking a piece of art) to fulfil a different task (like assisting travel and movement).
4. The inability to uniquely identify older artifacts which are not electronic or networked (like a painting).
5. The over reliance on Global Positioning Systems (GPS) to gauge proXimity to virtually marked out areas of interest. These systems are ineffectual because GPS fails to address: artifact mobility, complexity of environments, signal interference and inconsistency in internal and urban environments, and artifact uniqueness.
6. The high cost of – current – networked ambient devices.

Our system aims to solve these problems by using ambient devices and a Personal Digital Assistant in the role of a real-virtual SHIM to conjoin real and virtual worlds and we us the physical traveller (the visually impaired user) to 'walk the links'.

The Story So Far In our previous work we assert that lessons learned in the real-world mobility of visually impaired individuals can also be used to solve their mobility problems when moving around Hypermedia resources. Further, we likened Hypermedia use to travelling in a virtual space, compared it to travelling in a physical space, and introduced the idea of mobility - the ease of travel - as opposed to travel opportunity. Finally, we created a model of mobility that proposed a set of objects, techniques, and principles useful in addressing the travel and mobility issues of visually impaired users [9, **?**]. We have come to realise that visually impaired travellers move around an environment by answering the questions 'where am I?', 'where can I go?', and 'what can I use to help?'. The ease of movement is determined by the complexity of the questions, their sequence, and the returned results ability to inform the formulation of the next question. Previous attempts to answer these questions have used simple markers placed within the environment or on users [1]. These devices have aimed to bridge the gap between visual and audible mobility information and as such have focused on sensory translation. However, our system differs from these in that it uses hypermedia paradigms combined with our mobility models to help us understand the mobility requirements of a user within an environment and to enable those requirements to be fulfilled. In effect the user takes control of their own mobility as opposed to being passive receivers of static information.

Motivational Example/Problem The majority of visually impaired users say that they become disoriented and frustrated when they travel in complex and unfamiliar internal and urban environments [7]. Our scenario focusing on David may seem contrived but it does represent the real life experiences of many blind and visually impaired individuals [1]. It is within this context that we first started to think about helping to solve the mobility problems of visually impaired travellers. Imagine, a traveller running to catch a

[1] Used afterward as a general term encompassing the World Health Organisation definition of both profoundly blind and partially sighted individuals

flight, who can be directed to his gate based on artifacts encountered on his journey and knowledge of his final destination. Or a visually impaired traveller who can be directed around new environments (which would be previously inaccessible) with ease and confidence.
With the advent of the semantic web and Tim Berners-Lee's desire to describe resources (many of them real world resources) more fully the division between real and virtual will become more of a hindrance. We therefore thought that our system could be extended to other user groups. For example, walking into proXimity of Michelangelo's 'David' could display hypertext information from the local website, unique artifact histories, and other pre-searched information from the web along with annotation services and the like.

Synopsis We provide examples of the current state of mobility with regard to ambient devices concerned with the movement of visually impaired surfers. We briefly review the state of current related work in mobility technology and the concepts of hypermedia and ad-hoc networking. In effect we give a multi-disciplinary background to place the project in a general context. And then address similarities in other projects while highlighting differences with our own. Finally, we describe our initial developments and then give an overview of our system. A system which, automatically and dynamically creates ad-hoc networks from simple imbedded (invisible and embedded) ambient devices by using a Personal Digital Assistant as an egocentric user interface and a network hub. We will show how the system will work and how interconnections with sematic, grid, and web resources will be made. To finish, we will describe our method of using the HTTP protocol and stateless network connections to intelligently direct travellers from point to point.

2 Background

ENVIRONMENT - Ambient Devices At it's simplest Ambient Computing[2] has the goal of activating the world by providing hundreds of wireless computing devices of all scales everywhere. While the concept of generalised computational devices invisible but situated through an environment is relatively recent the technology to enable the concept is not. Ambient systems work by using infrared, radio, and inductive or electrostatic technologies to transmit information between devices carried by the user and a device fixed within the environment. When the user moves into range either the beacon – within the environment – or the user device can give feedback. Beacons are often placed at strategic points – say on a platform or railway concourse – to augment implicit waypoints or create additional explicit ones, and the pools of mobility information around them are known as 'information islands'. Ambient systems stem from the belief that people live through their practices and tacit knowledge so that the most powerful things are those that are effectively invisible in use. Therefore, the aim is to make as many of these devices as possible 'invisible' to the user, where applicable. In effect making a system 'invisible' really necessitates the device being highly imbedded and

[2] also known as ubiquitous or pervasive computing

fitted so completely into its surroundings that it is used without even thinking about the interaction.

USER - Egocentric Universal Access Through our work on other projects (TOWEL [6] and POLI [7]) we have become aware that single focus systems exist mainly because the user interface and the functional parts of a device are conjoined such that just one user modality is supported and one system functionality is addressed. Consider the example of a lift, in which a dyslexic user may have difficulty choosing floors and accessing lift functions because the lift user interface (in this case an LCD display) does not support their needs. Or the problem of how to notify a deaf person working in their office that there is a fire when the user interface to a fire alarm is only a siren.

KNOWLEDGE - Semantic Web The Semantic Web is the abstract representation of data on the World Wide Web, based on the RDF standards and other standards to be defined. It is being developed by the W3C, in collaboration with a large number of researchers and industrial partners. It is an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in cooperation. The development of ontologies will be central to this effort. Ontologies are metadata schemas (built using the OIL / DAML + OIL / OWL languages), providing a controlled vocabulary of terms, each with an explicitly defined and machine processable semantics. By defining shared and common domain theories, ontologies help both people and machines to communicate more effectively. They will therefore have a crucial role in enabling content-based access, interoperability and communication across the Web, providing it with a qualitatively new level of service – the Semantic Web.

3 Discussion

We aim to give a real world presence to hypermedia information by electronically marking physical artifacts and groups of artifacts with imbedded non-networked ambient devices. We aim to move descriptions of real-world node functionality, interaction protocols and interface specification, conceptual descriptions and groupings – of nodes – to the virtual world (Web). We propose a connected mobile device (like a PDA or 3G phone) be used as an egocentric user interface and computational hub to control devices and manipulate information structures – stored as HTML and XHTML on the web. In effect we have devices that represent anchors and nodes, and devices that are interfaces - both types follow hypermedia and Web rhetoric.

We expect minimal computational and interface functions to be present on the imbedded device but rather the device and the mobile interface to be used in combination. We aim to bring 'remote' information and control found on the web to the 'local' physical environment, and we expect to use semantic descriptions, disjoint and disparate hypermedia information resources (like the web or Grid), and enhanced searching based on accurate physical proximity to remotely described physically local artifacts.

We connect our imbedded devices to the internet using our mobile hub as the interface therefore we have small infrastructure costs, placement by domain experts is not required, the user-interface is removed from the physical world and is therefore flexible and egocentric, 'remote' hypermedia resources from the web – or other storage

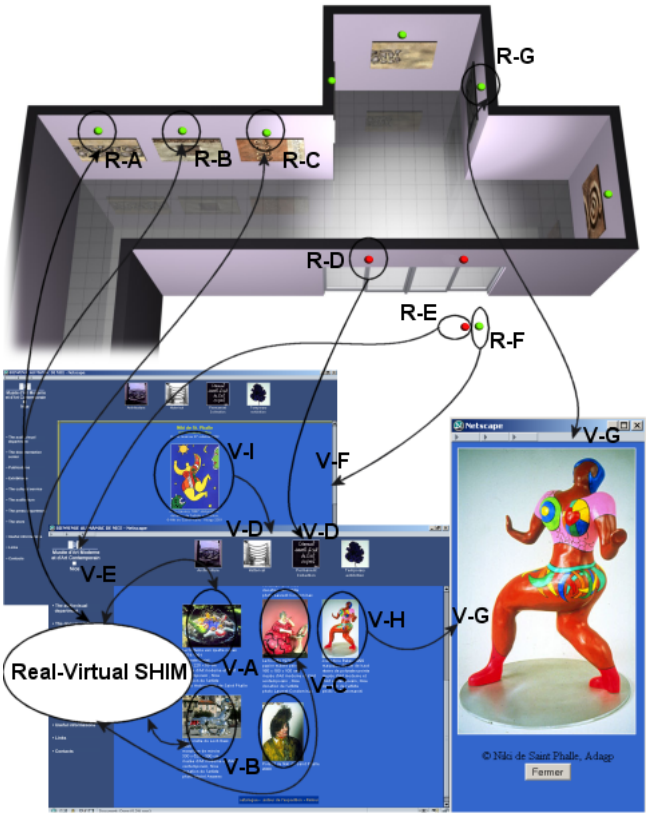

Fig. 1. Movement Scenario

paradigms – are constantly searched and presented to the user based on the real world nodes and anchors (and therefore artifacts) encountered which may also be moveable – like books in a library for example.

There are many possible ways to determine a person's position within a building; camera, infra-red beams, RFID tags, capacitive effect - even prediction might be possible in certain circumstances. However, in our particular application, it was an object carried by the traveller which needed to convey precise location. In fact now that we have contemplated the options we think that infra-red can provide the solution. Consider an infra-red emitting diode, what are its characteristics? Well apart from the output power, the relevant one here is 'beam half-angle' and therein lies the answer. Application notes for various components [12] show that the beam can have a very sharp cut-off, which means that a detector on the person will only respond within a well-defined area. This solves two problems; one of precise location and the other of 'adjacent channel interference'. And this solution has the other advantages of relative cheapness and low power. These emitters may be battery powered and mounted on the ceiling (with the appropri-

ate device chosen according to the required accuracy of the location and the mounted height.

Hypermedia - Hardware(artifact) Interplay proXimity is all about linking the real and the virtual and so the conceptual design of the system is focused on providing this linking (via the Real Virtual SHIM). Figure 1 shows this interlinking in the context of a real world art gallery (depicted at the top of the diagram) with virtual information about that gallery, and the art work within it, shown as a sequence of hypermedia nodes, in this case web pages (depicted at the bottom).
Beacons in the real world locate users to specific hypertext resources by transmitting the address of the location (Fig 1 R-E), in the form of the URI being entered. From this the hypertext start point (home page of the web site – V-F) can be distinguished and shown on a user device. In effect the focus of the interaction has move from the real (R-F) to the virtual (V-F). The hypermedia resource can now be browsed to find the appropriate exhibit (V-I to V-D). Directions to the exhibit area can then be given and focus switches back to the real world (R-D). At this point the user becomes the server and takes the virtual directions to find the real artifact. This is one big real world routing problem and as the artifacts are heterogenous, disparate, and distributed the task can be likened to hypermedia routing requests. Each real world node and anchor doubles as a point on a virtual map and using graph theory [11] the user is directed to the correct artifact location (R-A, R-B, or R-C). Once there the anchor point is activated and hypertext information about the artifact is displayed along with the annotated comments of previous users and a set of links to other related resources (V-A, V-B, or V-C).

4 Related Research

GeoNotes Positioning technology is often associated with locating people in geographical space. The GeoNotes system, however, positions pieces of information. GeoNotes allows all users to annotate physical locations with virtual notes, which are then pushed to or accessed by other users when in the vicinity. GeoNotes use GPS and DGPS, however this is only good for larger physical areas. Problems also exist with these technologies because they are not accurate enough to react to exact areas (measures suggest only an 18 to 6 metre accuracy level), they seldom work in buildings and internal environments, and are often very inaccurate in complex built up areas like cities [5].

HP Cooltown - Websigns HP Cooltown is a vision of a technology future where people, places, and things are first class citizens of the connected world, wired and wireless - a place where e-services meet the physical world, where humans are mobile, devices and services are federated and context-aware, and everything has a web presence. Cooltown propose that all devices should be connected, we think this creates an infrastructure cost that is static and unmanageable, interfaces and functionality that are inflexible, and information access that is too specific and therefore negates the intention of hypermedia and the web [4]. We also propose that devices in the environment are second class citizens (not first class) and that they cannot be networked without a user device being in range and used as a conduit for device to network communication [2].

Equator The central goal of the Equator Interdisciplinary Research Collaboration (IRC) is to promote the integration of the physical with the digital. In particular, it is concerned with uncovering and supporting the variety of possible relationships between physical and digital worlds [8]. The objective in doing this is to improve the quality of everyday life by building and adapting technologies for a range of user groups and application domains. Our proposed project is relevant to the research agenda of the Equator IRC as it relates the digital and physical worlds. However, projects in the Equator stable like Narrative, City, Artequakt, and AR do not address our key issue of creating a universal real - virtual symbiosis through hypertext information and semantic knowledge [14].

Auto-ID Auto-ID is a project to give everything in the world a unique ID through the Physical Mark-up Language (PML).

> Auto-ID technology will change the way we exchange information and products by merging bits (computers) and atoms (everyday life) in a way that dramatically enhances daily life in the all inclusive global arena of supply and demandthe supply chain.

Auto-ID [3] does not utilise semantic descriptions, does not take account unique artifacts (as opposed to products), and does not take into account ambient device control mechanisms.

HyperTag HyperTag is a system of infrared tags that can be detected by some mobile phones and with the addition of some software to the phone is used to point the onboard browser to a specific web address. It [10] is only used for delivering single page and source hypertext content, it does not address the issues of interface independence, control of ambient devices, Ad-Hoc networking, spatio-temporal searches over hypermedia resources, or semantic descriptions of unique real world artifacts.

5 Summary

The research is multi-disciplinary and cross-platform. Primarily the research will be useful to visually impaired pedestrians when travelling within complex and unfamiliar internal and urban environments. However, when complete it may be of use to all users who need mobile, location specific hypermedia information from multiple sources. These could include visitors to public information services, museums, and art galleries. We have a real case study in place, with the collaboration with the Whitworth Art Gallery we intend to demonstrate our system over 3-6 months with real users. proXimity is timely in that it uses new and evolving technologies across the knowledge, environment, and user domains (Semantic Web, Ontologies, IR, Bluetooth, GPRS) to create a novel and unique system [13]. We index physical objects using ambient devices and join the real to the virtual on an Ad-Hoc basis thereby creating large scale physical networks for information and control. In this way we address many of the problems associated with the partiality and transient nature of current and future networks in semantic and physical space. We then deploy a real application over this combined space to demonstrate the feasibility of our ideas.

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