

FACILITATING LEARNING IN AN INTELLIGENT ENVIRONMENT

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ABSTRACT

Ubiquitous computing has tremendous potential for framing learning, particularly in informal and socially constructed contexts. To reach this potential it is necessary for the current desktop-focus development of technology in education to be challenged through the design, development and testing of new ubiquitous prototypes for learning.

We define an intelligent environment as any space where ubiquitous technology informs the learning process in an unobtrusive, social or collaborative manner. In this paper, we present two ubiquitous devices for use in such an environment: the Experience Recorder and the iBand. The experience recorder is an embedded system that records the paths traveled by users – i.e. trails – in a particular place, for example at a museum or trade fair. It then recreates this visit in digital form, for example as a personalised website, enhanced for learning. The iBand is a wearable bracelet-like device that exchanges information about its users and their relationships during a handshake.

We develop our concept of a learning event and detail our approach to facilitation of these events in an intelligent environment, informed by theories of learning suited to an intelligent environment.

INTRODUCTION

Ubiquitous computing is the seamless integration of technology into the physical world, enabling digitally augmented spaces to provide information and services when and where they are required. As technology fades into the background, people are freed from the need to use a desk-based personal computer. The long-term goal of this computing paradigm is to create an ambient landscape of human-centered technologies that provide seamless assistance for people's everyday activities, rather than burdening them with technology.

Ubiquitous computing is the result of the convergence of several computing and telecommunications research areas (including computer architecture, intelligent systems research and context awareness) and although ubiquitous computing is developed on top of numerous technical innovations, it is fundamentally based on recognition of the essential role of social interaction, as well as interaction with artifacts and the physical environment.

Our particular area of interest is in facilitating learning in intelligent environments. Learning is no longer viewed only as a form of delivered instruction, undertaken within the confines of traditional educational environments. It is now understood as a social process

that happens at a time and place of the learner's choosing, continuing throughout one's life. It is collaborative, evolving and informed by a process of self-paced development. It is within this context that we seek to develop new ubiquitous technologies suited to tomorrow's learners working in intelligent environments.

We define an intelligent environment as any space where ubiquitous technology informs the learning process in an unobtrusive, social or collaborative manner. Thus an intelligent environment can be an 'aware' room or building, capable of understanding something about the context of its inhabitants or workers; it can be a digitally enhanced outdoor space – park, cityscape or rural environment; or it can be the environment created when peoples' meetings or interactions are augmented by wearable devices.

With the explosion of the World Wide Web in the mid-1990s, there was a massive increase in the amount of information available to people. It is possible that with the emergence of intelligent environments something similar will occur. Thus it is important that users can interact and productively manage this information space to suit their learning needs.

In this paper, we present two prototype ubiquitous devices designed to meet this challenge: the Experience Recorder and the iBand. Each facilitates learning in a specific and often complimentary manner. The Experience Recorder is an embedded system that records the paths traveled by users – i.e. trails – in a particular place, for example in a museum or at a trade fair. From the information collected it then recreates this visit in digital form, such as a personalised website, enhanced for learning. The iBand is a wearable bracelet-like device that exchanges information about its users and their relationships during a handshake. The social network built up over time may act as a knowledge resource to be consulted for potential collaborative problem solving.

AN INTELLIGENT LEARNING ENVIRONMENT

We are in the process of building an intelligent environment test bed at our research lab. It consists of proximity-based location sensing over ad-hoc wireless local networks, embedded networked sensors to capture multimedia content, virtual object exchange mechanisms for decentralised peer-to-peer wireless information interactions between individuals, digital content archives from centralised data stores, and wearable devices for information exchange.

While the environment is at the prototype stage, some of these components are further developed than others.

Each is designed to address open issues of relevance to the intelligent environments community, including:

- The expectation of interfaces and devices to underline human-centered interactions by leveraging existing communication forms;
- Determining what constitutes 'context-awareness' in a learning situation and in what ways can context-aware technology enhance the learning process;
- Identifying interaction design methods suitable for intelligent environments.

In attempting to address these issues, our goal is to deliver and collect information relevant to an individual's learning needs at any given time. Our motivation is that we do not simply want to react to technological change, but rather have a direct and pedagogically-motivated influence on it. Hence our focus on building new devices, designed to engage the learner in effective learning experiences.

THE EXPERIENCE RECORDER

The Experience Recorder is a system designed to enable the realisation of navigational learning. Navigational learning is a concept developed by Peterson and Levene (1) and involves three stages: trails, enactment and editing. Trails are learning paths followed by learners as they move through a learning environment (e.g. museum exhibits). Enactment involves engagement with the learning objects along the path, what in this paper we term learning events. Enactment may involve following a predefined trail from learning event to learning event, or it may involve the creation by the learner of something new. Editing is the process of refining a trail either upon reflection or pre-planning. We would also add a sharing stage in some cases, for example in teaching, or any sort of re-representation and transfer of knowledge.

The Experience Recorder uses proximity-based location sensing over ad hoc wireless networks. It can capture multimedia content, and transmit and deliver digital content to and from centralized data storage, or between users. Since the system uses proximity instead of direct contact with a computer terminal, users are freed to interact wherever they want within range of the network. Receivers are small and unobtrusive, and can work indoors or out. Together they form ad hoc networks that are able to locate individual users.

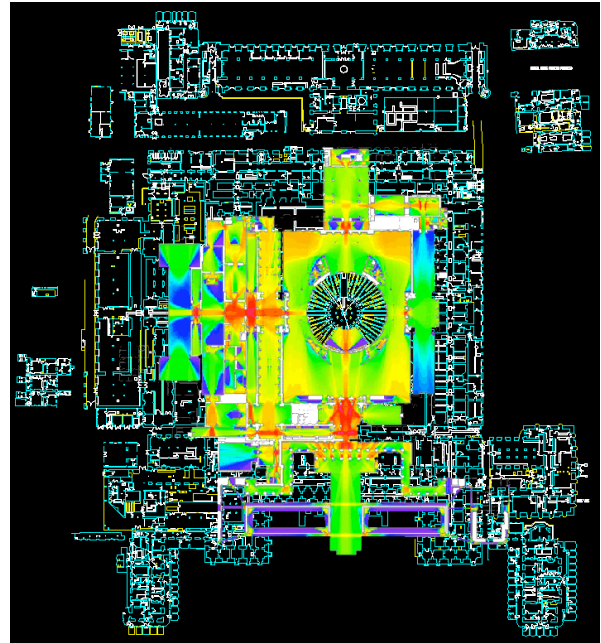


Figure 1. Simulated output from the Experience Recorder showing density of interactions.

At a server, locations, artifacts or exhibits can be classified as 'learning objects,' or more generally, interactions between learners and the computer can be treated as 'learning events,' which are described more fully below. The output can be represented pictorially as in Figure 1. It shows the density of interactions between learners and locations; interactions between learners could also be mapped. A trail record of locations for any individual or group of learners can be constructed, along with any evidence of collaboration – communication between learners, proximity between tags, the same artifacts or locations visited. This information can be re-presented back to the learners either at the learning location or remotely. The trail record can then be edited and shared by learners. The final, reflective, stage can be the most important from a learning perspective, and thus, we believe an important part of the system. Many technology-enhanced learning projects, both digital and location-based, often end at presenting the constructed information back to users, not allowing further editing or creative use by learners.

IBAND

A challenging component of any intelligent environment is the method by which the social interactions between people are captured. This project focuses on a particular aspect of this broad area, namely, face-to-face introductions via the handshake. These are captured and augmented with a technology-enhanced bracelet, termed the iBand.

The role that emotion plays in learning has been receiving widespread interest recently. Unfortunately, learning technologies based on desktop solutions can reduce expression, possibly with negative effect on learning relationships. Within the design community,

research into smart textiles and wearable computing has resulted in clothing that reflects people's mood, identity or characteristics. By leveraging these recent technological developments, we believe that wearable devices will be a core part of any future intelligent environment.

Collaboration and social interaction are key aspects of the learning process, but in many everyday contexts, people may not have the time to fully engage with one another when meeting. In collaboration with Media Lab Europe, we have developed iBand to investigate the issues surrounding this particular context of learning. Kanis et al (2) have investigated the potential of the iBand for social networking. In this paper we concentrate on its potential for aiding collaborative and social forms of learning.

iBand is a bracelet that exchanges information when one user shakes hands with another. The information provided by a user could be, for example, an email address, or area of research. Handshaking is detected via infrared (IR) transceiver alignment, combined with a sensed up-and-down motion synchronized on the two devices in IR contact. IR transmission is only activated when the user's hand/wrist are in a pre-calibrated handshaking orientation.

In the iBand's current instantiation, a new user begins by entering contact/biographical data and creating a personal LED logo at a kiosk. By using LEDs, we obtain a simple and flexible display by which the 'image' on the iBand reflects a particular characteristic or mood of the person you shake hands with. Additionally, a wearable visual broadens the scope of social interaction. In future versions the iBand could, for example, have a communication link with an intelligent room.

The data entered by the user is stored in a database, and the logo and a unique ID code are assigned to each device. Both the logo and ID are transferred to peer devices when shaking hands. During use, the LED display (a simple 5x5 grid pattern on the top part of the bracelet, lying flat across the wrist) cycles through the personal logos of all the contacts collected. The logos cycle more quickly as more contacts are collected. When the user returns to the kiosk they can download and view their list of new contacts.

RELATED RESEARCH

A number of projects share similar themes to our ongoing research. In the domain of experience capture, passive capture technologies – for example the SenseCam from Microsoft Research, see Gemmill et al (3) – let people record their everyday experiences without explicitly needing to operate a recording device. Sensors embedded in the device determine when recording occurs. Given the amount of possible data captured, a current focus of research is how to organize it. When explicitly recording data, the LifeBlog from

Nokia is designed to allow users to keep a multimedia diary of the data (photos, videos, text messages etc.) collected via their mobile phone; see Starvas (4). The software then simply stores the data in chronological order.

The RAW project aims to give a sense of the experiences of everyday life, under the premise that having this sense might be helpful in improving understanding and relations between people in different cultures. The device is an audiovisual recorder, combining a digital still camera and a stereo audio recorder, which records the 60 seconds of sound before and the 60 seconds of sound after a picture is taken. No editing of data occurs – the experience is recorded in its raw form. See Bitton et al (5)

Locative media allows the augmentation physical space with digital information. Examples include Urban Tapestries, a project we have helped to trial; see Walker (3). It consists of software running on a PDA or mobile phone that allows people to create and access location-based information. Current work focuses on the social implications of the technology when people exploring and share their experiences of the city. In a similar but different vein, Mobile Bristol aims to provide what they term 'digital media experiences' such as soundscapes and games to users. The aim is to research the ambience of physical places. Particular applications include CitiTag (7) and the Queen Square Riots project (8).

Two projects within the EU's Disappearing Computer initiative outlined approaches for the possible use of ubiquitous technology for learning. Paper++ experimented with augmenting the properties of printed-paper so that it can directly interface with all types of digital media through a cheap and simple pen-like device; see Sellen et al (9). SHAPE developed artifacts that communicate with one another as part of room-sized assemblies that provide groups of people with experience of large-scale mixed reality. The idea is that they can be placed in public spaces to establish new kinds of engaging and educational social experience. Tangible interfaces using pressure mats, video-tracked and bar-coded physical props were developed so as children could navigate a story collaboratively. See Bannon et al (10).

Audio Aura explored how peripheral awareness of relevant office activities could be enhanced through the use of ambient sound in a mobile setting. The combination of large wireless headphones, active badges and audio was too cumbersome for long-term use, but nevertheless an initial understanding was gained regarding potential interaction in new auditory spaces. See Mynatt et al (11). eClass (12) and E-Chalk (13) are ubiquitous computing projects aimed at automated capture of the "lecture experience" for later access by students and teachers. Lectures were complemented with a presentation on a large interactive

display. The teachers or students could share prepared materials during the class with all actions by the presenter, the contents of the display at each instant, and audio and video recordings captured and stored for later review.

Both of the above systems are focused on the lecture environment and on its particular style of learning. No account is taken of the rich variety of learning styles and interaction scenarios that occur outside of the lecture hall. The premise is that simply by capturing the 'experience' learning will be aided.

As distinct from other work, our aim is not to record an entire live experience, nor to capture internal cognitive workings. Our focus is on capturing those salient moments that define the learning process, and the Experience Recorder and iBand each capture data at different points of interaction. The goal is to avoid overly complex technical systems or cumbersome devices in favor of relatively simple but robust interface technologies, which link physical spaces with virtual ones in a two-way exchange.

THEORIES OF LEARNING SUITED TO THE INTELLIGENT ENVIRONMENT

To build ubiquitous learning devices, it is important that their design and context of use is informed by learning theories. Many of these theories can be mapped to three pedagogical approaches to education: behaviourism, socio-cultural and constructivism; see Conole (14).

While we will not go into these in detail here, we offer a summary of three particular approaches: *constructivism*, *socially constructed* and *experiential learning*, that have informed our perspective on learning in any intelligent environment. For an extended discussion of the theoretical aspects of ubiquitous learning, see Walker and Winters (15).

Constructivism. Constructivism is an approach to learning focused on self-directed activities. The purpose of these activities is to aid the learner in building their own understand of a given concept. Learning, in this context, often takes place using a 'construction toolkit' of some sort, for example a simulation. The rationale for engaging in this type of learning is that it is more learner-focused than other approaches.

Socially constructed learning. Socially constructed theories view learning as a process of social participation where knowledge is socially constructed. Learning is about our experience of the world and our engagement with it, in which dialogue forms a central tenant. Within this theoretical framework, models of learning such as distributed intelligence by Pea (16) are relevant, as they view knowledge as not only socially embodied but inherent also in the designed environment as well as in artifacts.

Experiential learning. Experiential learning by Kolb

(17) focuses on the relationship between experience and knowledge creation. Experiences are viewed as the foundation of learning which is further enhanced by reflection.

We view learning in an intelligent environment as having the potential to form new communities of practice, where the technology may lead to the formation of, or enhance existing, learning communities. In this manner, new technologies do not make existing theories obsolete. On the contrary, the above approaches become increasingly important, though their focus shifts from human-computer interactions to human-human and human-environment interactions.

Since technology pervades so much of our environment, an even broader model can be useful. Van de Velde (18) has conceptualised the world itself as a type of computer, and he suggests broadening our notion of architecture to include information; see also Walker (19). This draws on the work of Alexander (20), whose 'pattern language' centers on 'occupational narratives.'

LEARNING EVENTS

Learning in an intelligent environment can occur in a number of different contexts. The learner might be interacting with a piece of knowledge, communicating with another learner, traversing a particular learning path or reflecting on experiences gained. In e-learning systems, 'learning objects' are cohesive pieces of learning material, usually stored in a database, and learners create time-ordered trails through them; see Schoonenboom et al (21). Peterson and Levene (1) postulated that objects such as museum artifacts or exhibits could act as real-world learning objects (in a technical sense, not the broader sense in which museums already view artefacts as objects for learning).

We add a time dimension to this in the form of *learning events*. We define a learning event as an interaction that contributes to the learning process. For example, the interaction between the learner and a mediating tool; the learner's proximity to a painting or exhibit; the exchange of information during a meeting; the making of voice recordings or the taking of pictures.

Learning events are important because over time they form a navigational trail of the process by which the learner came to their current state of knowledge, but our model views both the knowledge and the trail as dynamic. It captures learners' process of exploration include avenues that they may have explored and discarded, and allows for more flexible editing and re-representation of trails.

More significantly, it captures social interactions as well as encounters with static locations or objects. Social interaction is an important part of learning. In any intelligent environment it would be beneficial to know when people are meeting. In particular, first meetings

and introductions where a learner's navigational trail may begin is a significant node to capture. Addressing one of the key aspects of ubiquitous computing research, namely that interfaces leverage our natural communication modalities, iBand captures face-to-face interaction via the handshake, and the Experience Recorder can record when paths cross or progress together.

SAMPLE USAGE SCENARIO

Jenny is interested in marine biology and in particular the specimens that inhabit the deep sea. She has read widely on the subject, and when an exhibit on the subject opens at her local natural history museum, she decides to go. Before making the trip she remembers to bring her iBand, which contains information she may want to exchange including, for example, her email address and her subject of interest and expertise. Upon entering the exhibition, her presence is detected and her particular expertise noted by the intelligent environment. As she progresses through the exhibition space, following her own path, her trail is recorded as a sequence of learning events. When she comes to a computer terminal, the information she accesses is personalized to her level of expertise. It is at one of these stations that she strikes up a conversation with Clive and they introduce themselves to each other as they shake hands. Lights on their iBands indicate that information exchange occurred. Clive's particular topic of interest is insects and while glancing at his iBand he sees that Jenny's trail through the exhibit included a stop at the notebooks and scientific papers stand. They begin talking about this as he too enjoyed aspect of the exhibit.

At the end of the day, the intelligent environment notes Jenny's leaving and emails her a link to the trail she took through the exhibit, which can be edited and shared, and contains links to further information. She will combine this with the information collected with her iBand to produce a learning resource, aiding her reflection on the day's events. Clive similarly benefits from following up the links he received from Jenny's iBand.

DISCUSSION

The challenge of ubiquitous computing is to design and build systems that are a tool for augmenting human capabilities rather than seen to replace them. In the context of learning, this is very important, as any ubicomp tool cannot be viewed as deskilling the user. It must encourage skills development in a manner in which the learner is comfortable and engaged with. We believe that by providing a view of their learning path through a space, which would otherwise be hidden, our prototype will allow the learner to reflect in a manner that would not have been possible without ubiquitous technology.

As learners progress through an intelligent space the ubiquitous technology should not impinge on their

learning in any manner. As in Weiser's (22) vision, the technology should be 'calm', aiding the learner to interact and explore in new ways, engaging their analytical thinking.

As with any application of ubiquitous technology, how the user perceives it can have major implications for take up. A key aspect affecting user perception is privacy and context of use. In our view any intelligent environment must deal with privacy in a forthright manner. For example, with the iBand, the user only makes available data that they are comfortable with exchanging; see Kanis et al (23). In intelligent environments, transparency is essential: with our system users have full access to and control over their personal information. At all times we seek to make users aware of the functionality of our system. Our interaction mechanisms are designed to augment human practices of communication.

While we try to use learning theories as a basis for technological development, it is quite possible that ubiquitous technologies will in turn have implications for theory. In the technology community, the terms 'ambient' and 'ubiquitous' have slightly different meanings, but to us this makes little difference, for we are concerned merely with the fact that where once we regarded a computer as part of a learning environment, we must now consider the environment itself as a computer, whether accessed via mobile or ambient means. We term this type of activity 'non-interactive computing' - the ability to interact with a computer with natural and social gestures such as moving around a space, or exchanging greetings; all input and output devices can be visually and/or perceptually invisible until needed.

CONCLUSION & FUTURE WORK

Facilitating learning in an intelligent environment is not a trivial task. In this paper we have detailed two approaches, one broadly focused on environments, and one specifically focused on human greetings. Research on learning trails can view objects and events as discrete events, but an evolving process requires a dynamic model, and more work is to be done in this area. Determining just what constitutes learning objects and events is a question of granularity, informed by context.

A parallel challenge to capturing and representing trail and event data is turning the vast repository of information into a useful resource. Some of our other work, and that of our colleagues, involves data mining and semantic indexing of digital data. Social networks also are an important related area of study for the sharing of trail data. Our work with both the theory and with specific technologies will evolve in parallel, informing each other as their own respective trails meet.

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