# Pervasive Media: Delivering 'the right thing in the moment'

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**Abstract:**
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## Abstract

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This paper considers the implications for technology and application research. We describe the need for: an extensible and scaleable context framework with privacy, trust and security policies embedded; new modes of interface between the physical and the digital environment; and a programme that builds expertise amongst practitioners as the technology develops in its early stages.

## Pervasive Media

*Pervasive Computing*[1] has been an active research field for more than a decade [26] [13,14,17,18,25,27]. Over the last few years, computing and communication technology has created a world in which people increasingly carry devices that provide a potential platform for the pervasive computing vision - small, powerful computers and phones connected through wireless networks to digital content on the internet. For some time, our vision has been to utilize this platform to deliver compelling experiences through *pervasive media* – rich, context-sensitive, digital media delivered to users at just the right time and place.

The growing availability of location-based services delivered on GPS-enabled consumer devices indicates that we may be on the cusp of a potential explosion in media and information delivery triggered by a range of physical, digital, and social contextual triggers[2]. However, the full realization of that potential, particularly for pervasive *media* services, will depend upon the emergence of both appropriate technology and experience design expertise.

### Technology

Three main technology strands are needed to drive the potential for a new generation of pervasive media services:

- 'Context-smart' devices and new interaction mechanisms with the potential to win mass market acceptance and enable the delivery of high value services.
- A framework for acquiring, updating, applying and controlling access to context data in a manner that is distributed, scalable, extensible and safe.
- An authoring capability that enables the creation of context-based media services, developing awareness and expertise and feeding back into platform research.

The clear links between these three elements cause us to emphasize now the integrated and iterative way in which the technology platform as a whole should be developed, made available and applied.

### Design Expertise

Pervasive media is properly understood as a new *medium* that has the potential to grow into a major revolution in the multimedia field. However, this new medium is in its infancy and it is necessary to build a strong community of expert practitioners to foster that growth by:

- Developing and demonstrating novel interaction mechanisms more suited to physical environments than are current desktop metaphors
- Establishing design guidelines for the medium through experimental trials and analysis
- Developing a deep intellectual framework for experience design
- Enabling a wide spectrum of practitioners to get their creative hands on the technology in a form that enables them to explore its capabilities and acquire new design skills
- Fostering community interaction through Knowledge Transfer Networks.

### Emergence

The end goal of the research is to enable the *emergence* of a new pervasive medium with clear user value, appropriate technology and a community of expert practitioners. Emergence is crucial here to avoid the trap of

[1] Also known as Ubiquitous Computing.

[2] For example, where a user is and who they are with, their bio-signs, RSS feeds and instant messaging connections…

technological determinism. A century ago, the Lumiere brothers, inventors of the first cinematograph, thought that they created a device for capturing and reviewing moving photographs. It took time, and the vision of others, for the true value of this invention – movies with compelling narratives and wonderful effects – to emerge. Our aim should be to fast-forward this emergent process by sharing our technology and expertise as early and as widely as possible, first with research community and then with the wider public.

## 1. Interaction Mechanisms

We are creating a platform that enables devices to participate in a network of appliances whose data and interaction mechanisms contribute to a palette from which context services can be built and delivered by connecting devices and combining physical, digital and social context.

A number of new smart materials are becoming available to add to this design space of connected, context sensing, appliances. In particular imaging as a sensing capability is important because of the large penetration of camera phones and its huge potential to add to the delivery of context services. For example, a number of indoor and outdoor robotic systems [e.g.12] have been developed in which video data captured from an omni-directional image sensor is matched against a database of stored images captured at regular intervals in the physical environment to estimate position and orientation. An alternative approach is to match standard planar camera images against stored 3D models of the environment [22].

Imaging can also provide the basis for the richer presentation of digital information pertinent to the physical location. At its most rudimentary this information can be text based; superimposed over the visual projection of the displayed objects for example to identify the location of subterranean water pipes or to visualize virtual graffiti left by members of an online community. More interestingly the virtual can be used to augment or transform the visual appearance of the physical world. For example generating a visual overlay to create a composite between the virtual and physical realities would be useful in a game playing environment It is also possible to use this technology to populate real worlds with virtual characters and have them interact with it in a physically plausible fashion [see for example 9].

### Technical Challenges

(1) To create an extensible *device architecture* that has the simplicity of desktop PnP yet the connectivity reach of wide area interactions. Our expectation is of PAN & LAN connectivity that will need to address the problems of device ambiguity and selection, particularly as the number of connectable devices present at any moment will continue to increase as more categories of appliance become 'wired' and network ready. Our architecture must allow flexible, dynamic combinations of modular components that can be configured on the fly to meet a user's in the moment needs, whilst avoiding the solicitations of unwanted devices and ensuring data privacy. Thus, the technical issues to solve are:

- Device discovery;
- Addressing and connection;
- Trust and privacy of content delivery;
- The maintenance of sessions across intermittent connections and combinations
- Configuration with minimal to no user intervention

(2) To design appropriate and compelling user *interaction mechanisms* for operating in a world of fused physical and digital experiences. To achieve this goal, it will be necessary to extend the theoretical and practical boundaries of interaction design to include an understanding of how to map physical acts onto meaningful digital actions (and vice versa). The technical issues include:

- Developing a vocabulary and grammar of action that is appropriate for interaction with services in a world of pervasive media;
- Real time discovery of pervasive media services available in any given situation
- Selection from the services available;
- How to design compelling interactions within a service given the situation;

(3) Systems research at the sensor level is proposed to enrich the interplay between the digital and physical components of experience. In this research strand we will incorporate accelerometers and smart materials and extend the use of the camera as a sensor through object and gesture recognition and an extension of the limits of visual registration and overlay. Technical issues include:

- Sensor data capture and interpretation;
- Visual capture and robust object recognition in real world situations;
- Real time registration of digital images and physical features;
- Small scale movement and gesture recognition.

## 2. Context Framework

At the heart of Pervasive Media is the context data used to trigger the right services in the right moment. Context may refer to physical, virtual or social circumstances. Context derives from physical sensors such as GPS, from digital resources such as electronic presence services, and from user input. It may be used raw, such as in the form of pressure or audio data, or processed to create higher-level context data such as identified human presence in a known location.

Rather than being bound within a single application, context data is first-class data that is acquired, distri-

buted, processed and consumed across many services over a potentially global scale. We expect its production to be motivated in many ways, financial and otherwise. We expect it to be traded, and its value to be multiplied by a host of Pervasive Media services.

Academic and industrial researchers have been investigating context in the field of pervasive computing (as well as robotics) for many years [23]. Research has focused on individual systems that take the readings from many types of physical sensors and provide services as a function of them. Sensors for pervasive computing are sometimes combined with a simple network interface and processor to form a node in a sensor network. Much work has been concentrated on middleware that can abstract a contextual attribute such as location from whichever form of location sensor is used [10] and *sensor fusion* in which the results of several types of sensor are combined to improve accuracy in any one of them or to provide higher-level interpretations [11].

For Pervasive Media a much more interoperable view of context data is required, recognizing that sensing is increasingly a global phenomenon with attendant issues such as scalability of distribution and processing, heterogeneity of data and device types, sensor mobility and personalization, and the need to manage data quality [1, 3].

Given that personal data is involved, privacy and trust are both important factors affecting adoption of context-triggered services. We expect users to maintain some sensitivity about certain types of context data such as location information; and still greater concern about more intimate data such as their heart rate. Even if the user is happy to provide such data to certain parties on certain conditions, they will want to be categorically sure that agreements are not broken. Control over context data can be broadly broken down into two areas: managing trust in the services that mobile users encounter, and managing the flow of context data in accordance with the level of trust invested in each particular case. Existing research has considered automated support for trust decisions concerning the use of mobile technology [7], and how to implement trusted or "Hippocratic" databases [2]. In terms of control mechanisms, researchers have considered: how to construct "intuitive" abstractions for managing the flow of personal data, such as "Virtual walls" [16]; how to obfuscate users' presence [5]; and how to provide an audit of the personal data held by pervasive services [21]. But little of this research is informed by how users actually make trust decisions [17]; and far more investigation is required into effective control mechanisms for privacy.

Beyond the research community, there are a number of efforts underway to develop services and applications that use or capture context. The initial commercial efforts are fairly basic and focus almost exclusively on physical location and location based services. In many case these solutions require specific actions from users to enter unstructured information about their current context. Some of the more popular attempts include Twitter – a service based on the question "What are you doing? – and Yahoo's FireEagle – which stores information about a users location which can be shared with their friends or services. In this space HP is already at the forefront with the work on mediascapes [25]

## Technical Challenges

Our goal is to create a pluggable platform that supports the production, distribution and processing of multitudinous context data feeds in an extensible and scalable way, independently of devices and services, and which supports a broad range of policies with regard to privacy and other factors influencing adoption. This platform is used by service providers and solution authors to create and deliver context specific user experiences. However, the goal is not to impose physical or commercial centralization of a platform. Neither is it a goal to impose any particular representation of context data. Rather, the platform is conceived of as a specific architectural realization of a broader framework that can accommodate the entire market of context services and context players.

The creation of such a framework, and its platform realization, presents a number of technical, social and business challenges which are summarized below.

- Context provision – In order to enable rich applications, the platform will provide a layer of relatively high-level context abstractions in addition to raw feeds. We will need to determine the critical high-level context data that applications will benefit from the most, and the major challenge will be to derive methods such as translation and interpretation for robustly achieving them.
- Context discovery – To create a Pervasive Media service, an author needs to know which sources of context data are relevant to the circumstances of interest, out of all the many context sources that exist. A major challenge for the framework is to integrate all the context sources into a navigable collection that can be efficiently scoped.
- Context routing – Context data will be generated by trillions of sources and consumed by a comparable number of services. The platform will need to tackle the efficient, scalable and accurate routing of context data, rather as IP networks manage this for the Internet.
- Privacy, trust and protection of information – The issue of privacy must be dealt with in order for this technology to be accepted in the market place. Any framework for protecting privacy is partly legal and partly social, but technical advances can also contribute greatly to the solution. The first challenge is to support a "pervasive web of trust": an effective but not too onerous solution to the problem of supporting users' trust decisions as they encounter mobile services. The question then remains as to how users control the flow of personal information to services. The solution will need to include mechanisms for imposing privacy constraints, for obfuscating per-

sonal data, and for auditing personal information held by services.

- Information diversity – There is much debate over what constitutes contextual information and how different kinds of information can be used. This debate is likely one that will continue, the platform we are creating will need to deal with such diversity by supporting a flexible information model that can be efficiently navigated, organized and accessed in many different ways.
- Device and service diversity – Choice is the key word here. We have to enable choice on the part of the user. Mandating a specific device and or service combination will not provide the right kind of platform for either users, service providers or content authors
- High availability, performance and low overheads – These are important characteristics of any platform and a requirement for satisfying user needs and business objectives in deploying and supporting a platform.

## 3. Authoring context-based experiences

The widespread adoption of pervasive media is currently limited by the technical difficulty of producing and delivering it. We believe that the potential of the medium can only be realized by radically transforming the means of its creation such that *anyone* - designers, media makers, artists, students, game developers and many others – can create, distribute and deliver pervasive media pieces. Such a transformation will lead to the emergence of everyday *authoring* of pervasive *media* rather than the specialist *development* of pervasive computing *applications*. Creation in the new medium will become similar to the creation of web content - within the grasp of many – and the resulting explosion of pervasive media will begin to emulate the rich blend of high-calibre professional and enthusiastic user-generated content we see on the web today.

The key to achieving this transformation is to provide easy-to-use media creation, publishing and consumption tools within an authoring and delivery framework that is accessible to a wide range of people beyond computing specialists..

The framework should be made available to potential media authors as quickly and as widely as possible through collaborative trials and public releases. This methodology harnesses the power of mass innovation at a crucial early stage in the emergence of the new medium. Rapidly expanding the number and types of people who are able to explore pervasive media, greatly accelerates the development of expertise in the new medium and the identification of real user value.

Previous research on the creation of pervasive computing applications has tended to fall into two broad strands:

- *Rapid prototyping toolkits* that provide re-usable components for pervasive computing, such as in the Cyberguide project [19]. Dey et al [10] provide a useful review of this approach and describe a comprehensive architectural framework based on a variety of "context widgets". Their architecture allows sensor, interpreter and the other widget types to be composed into larger systems through standard messaging interfaces, and for such widgets to be shared between different applications. This provides a rich and coherent toolkit that should ease the implementation of context-sensitive applications, particularly if they are to be distributed among different devices, but is primarily aimed at supporting skilled system developers.
- *End user programming tools* that are aimed at a broader range of application developers but which tend to be limited only to small-scale tasks. For example, iCAP is a visual programming system intended to enable end-users to develop context-aware applications modeled as if-then rules [24]. Topiary has similar aims but adopts a programming-by-example approach [20]. The InAuthoring environment allows mobile stories and simple games to be created by connecting geo-located nodes containing media content into a graph that establishes the flow of the story or gameplay [4]. In a similar manner, the Mobile Experience Engine allows the designer to set up a series of states, each of which has associated content, and specify the conditions under which the state should be changed [6].

Although valuable, this prior work has limitations. The *rapid prototyping* approach facilitates application development by skilled computing professionals but fall short of our goal of enabling the *everyday authoring* of pervasive media. The *end user programming* approach does address this objective but tends to emphasize "programming in the small".

From this perspective, we would claim that our own work on the mediascape framework (aka mscape) [13] actually represents the state of the art for pervasive media authoring, albeit in the intentionally constrained area of standalone location-based mobile applications. The framework supports rapid, everyday authoring while allowing more expressive scripting if required, and may be extended through plug-ins. It has been validated experimentally and adopted by a sizeable authoring community.

Beyond the research world, there has also recently been a very fertile explosion in the production of *mashups* – ad hoc web applications built on publicly available APIs (like Google maps), web standards (like RSS), and accessible editing tools (like Yahoo Pipes). Mashups are in essence a form of programming by composition, an approach that we intend to combine with a reworked version of the proven mediascape framework in our ongoing research work, as outlined below.

## Technical Challenges

- **Meeting the diverse needs of pervasive media authors**

  Consumers and casual authors need simplicity while application programmers may require expressive power. Media designers will focus on integration of existing rich media whereas web developers may want to build mashups. Our challenge is to provide an integrated framework that supports all potential authors within a common framework, albeit with specialized authoring tools.

  ---------- > *increasing technical skill*

  Consumers | Casual authors | Media designers | Web developers | Application programmers

  *increasing numbers* < ----------

- **Giving meaning to context data**

  Pervasive media is about context – delivering the right thing in the moment. A key technical challenge for the authoring framework is to present contextual information to authors at an appropriate level of meaningful *abstraction*. Too low a level of abstraction may require authors to deal with raw context data, such as the output of a set of accelerometers attached to a user's body. Too high a level of abstraction might expose authors to inferred contextual semantics, such as the affective state of the user, that are likely to be fragile in practice.

- **Accessing sources of context**

  Contextual information is often available from a variety of different sensors and services; for example a user's location might be derived from GPS, CellID, WiFi triangulation or a range of other technologies. One of th*e tasks of* the author is to specify which sources of contextual information should be used in the piece of pervasive media under development. For example, would it be better for authors to specify, the more abstract *location*, which might be implemented differently in different settings, or the more c*oncrete GPS* , which would give the author access to that sensor's limitations?

- **Specifying responses to contextual cues**

  A primary task of a pervasive media author is to specify how media delivery should respond to contextual cues. Here, there is the familiar trade-off between ease-of-use and expressiveness. A casual author might prefer to select from a suite of predefined responses whereas *an exp*erienced programmer might prefer a full-blown, flexible scripting language.

- **Deploy*ing* pervasive media onto a distributed delivery platform**

  A typical pervasive media application might involve a mobile device with off-board sensors, offline services and objects in the environment such as a situated display. How is the application to be bound to this set of equipment? Design time binding might be simpler for authors but run time binding might be more flexible.

- **Dealing with the limitations of pervasive technology**

  All pervasive technologies have limitations. For example, GPS sometimes cannot get a fix and always has a small error when it does. Wireless connectivity is often intermittent and online services might be unavailable even when they can be reached. We subscribe to the view that such technology *seams* should be acknowledged and made visible to authors [8]. But how exactly should such limitations be exposed to authors at design time?

- **Authoring for multi-user experiences**

  Creating networked multi-user experiences is technically demanding because of issues such as data synchronization and latency. If we are to enable a broad spectrum of media creators then we need to find ways for these experiences to be built without the author having to address all the associated issues.

- **Ancillary factors**

  In addition to these core issues, there are a number of related questions. How should we handle rights-restricted media or allow authors to protect their output? What about sources of context data that require user authentication or that levy charges?

# Summary

Pervasive media is significant opportunity arising from the disciplines of Pervasive Computing. The promise is of value created by delivering the right experience in the moment. Successful ecosystems will require an integrated approach to three areas of research:

- Context-smart devices and interaction mechanisms for the delivery of Pervasive Media;
- Context management that is scalable, distributed, extensible and safe;
- Authoring tools for context-based experiences to kickstart the emergence of value and expertise.

These three strands of research are closely interlinked. Any successful approach to resolving them will need to be holistic, exploratory and iterative, and will require a combination of technical, social science and design research skills. Discovering and responding to real user value will be essential for success. As new sensors, smart materials and media delivery mechanisms emerge and better use is made of visual information, a range of smart applications, delivered through service integrated devices, will create a new science and art of experience delivery.

In addition to technology insight, a focus on experience delivery through a deep theoretical framework and practical explorations that give potential authors and con-

sumers early exposure to evolving technology, will be key to informing the emerging architectures and device designs and to building a community of practice well placed to deliver commercial value.

"Now is the time to seek out new applications, new revenue streams and improvements to business process that can come from augmenting the world at the right time, place or situation." (Gartner, Dec 06)

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