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# Ubiquitous Mobile Information and Collaboration Systems

Second CAiSE Workshop, UMICS 2004  
Riga, Latvia, June 2004  
Revised Selected Papers

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Luciano Baresi Schahram Dustdar  
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# Ubiquitous Mobile Information and Collaboration Systems

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## Preface

Over recent years most business processes have changed in various dimensions (e.g., flexibility, interconnectivity, coordination style, autonomy) due to market conditions, organizational models, and usage scenarios of information systems. Frequently, information is relocated within a geographically distributed system according to rules that are only seldom defined as a well-codified business process. This creates the need for a software infrastructure that enables ubiquitous mobile and collaboration systems (UMICS).

The anywhere/anytime/any means paradigm is becoming the major challenge in conceiving, designing, and releasing next-generation information systems. New technologies, like wi-fi networks and 3rd-generation mobile phones, are offering the infrastructure to conceive of information systems as ubiquitous information systems, that is, systems that are accessible from anywhere, at any time, and with any device. Ubiquity is not yet another buzzword pushed by emerging technologies, but is mainly a means to support new business models and encourage new ways of working. This new wave of UMICS will exploit the knowledge developed and deployed for conventional information systems, but will also need new concepts, models, methodologies, and supporting technologies to fully exploit the potentials of the enabling infrastructure and to be ready for the challenge.

Moreover, people need to move across organizational boundaries and collaborate with others within an organization as well as between organizations. The ability to query the company's distributed knowledge base and to cooperate with co-workers is still a requirement, but mobility brings new access scenarios and higher complexity. Therefore, some issues also arise about how to enable users to retain their ability to cooperate while displaced in different points of the enterprise, the role of context and location in determining cooperation, and the support for ad hoc cooperation in situations where the fixed network infrastructure is absent or cannot be used.

The approaches and technologies for supporting these new ways of working are still the subject of research. Nevertheless, they are likely to "borrow" concepts and technologies from a variety of fields, such as workflow systems, groupware and CSCW, event-based systems, software architectures, distributed database systems, mobile computing, ubiquitous information systems, and so on. A particularly interesting line of research is exploring a peer-to-peer paradigm enriched with sharing of abstractions, in which each network node is both a potential user and an information provider for the other members of the community.

June 2004

Luciano Baresi  
Schahram Dustdar  
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# Paper on the Move

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**Abstract.** We examine the properties and use of paper in everyday settings and discuss the motivation for retaining paper as an information medium. In particular, we consider the use of paper maps and guidebooks by tourists during city visits as an example of a mobile and collaborative environment. We then go on to present recent developments in technologies for digital paper and how they can be used to seamlessly integrate digital and printed information.

## 1 Introduction

Despite the emergence of digital technologies for capturing, managing, retrieving and processing information, paper persists as a fundamental resource for many human activities. It has therefore continued to be of great interest to the computer-supported cooperative work (CSCW) and human-computer interaction (HCI) communities. They are interested in studying both the properties of paper and how we use it, with a view to better understanding why it remains as a truly ubiquitous information medium. On the one hand, they want to use the results of their investigations to influence the design of digital technologies, with the ultimate aim of being able to replace paper. On the other hand, some researchers argue for the retention of paper and instead strive for means to interweave paper and digital media, enabling users to freely move back and forth between the printed and digital worlds.

In this article, we want to present the case for retaining paper and examine the move towards digital paper. While several projects in the past have sought to bridge the paper and digital divide, recent technological developments now make this a realistic option in some application domains and first business solutions are emerging. At the same time, current research opens up many exciting possibilities for the future in terms of whole new ways of interacting with paper.

Here we will focus on the potential use of digital paper in mobile environments. As a particular application domain, we will consider tourism which has been the subject of many projects in ubiquitous computing and mobile information systems. Typically, PDAs are used to provide tourists with, possibly personalised and context-dependent, digital maps and guides. Although many digital forms of tourist information are available nowadays, studies have shown that they are rarely used during visits, where paper continues to prevail in the form of maps and guidebooks. We will describe how technologies for digital paper could be used to support tourists and outline a demonstrator project for the Edinburgh festival that we are currently developing.

We begin in Section 2 with a discussion of tourists on the move, examining typical activities and their use of paper. This is followed in Section 3 with a general examination of paper and the argument for its retention rather than replacement. In Section 4 we present various technologies for digital paper. Section 5 considers various issues of tools and infrastructures to support digital paper, in particular providing an overview of our work on developing a general framework and authoring tool. Section 6 then describes some applications that we have developed and also a tourist demonstrator currently under development. Concluding remarks are given in Section 7.

## 2 Tourists on the Move

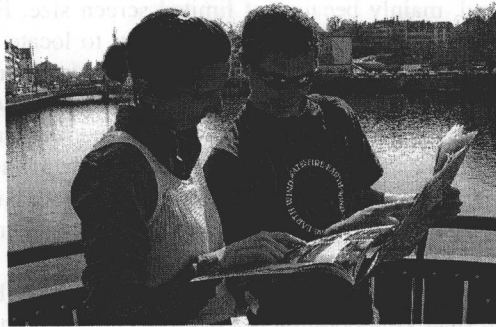
Tourism is a domain with considerable potential for the use of mobile technologies and a number of research projects have developed PDA-based tourist guides, for example, Georgia Tech's Cyberguide [1], the Lancaster GUIDE system [7] and Xerox Parc's electronic guide [25]. However, commercially available digital guides have had little success and paper maps and guides continue to be considered the essential tourist accessories.

To understand why this is the case, it is necessary to carry out detailed studies of tourist activities during a visit to a city. In particular, it is important to know *how* maps and guidebooks are actually used by tourists. To date, most studies in tourism have been concerned with the effect of tourism rather than the tourist experience itself. Recently, Brown and Chalmers addressed this by carrying out an ethnographic study of tourists visiting cities [6]. Data collection in their study involved observing and taking video recordings of tourists as well as accompanying tourists on day excursions and generating video diaries of the day.

A tourist experience of a visit actually has three phases — pre-visit, visit and post-visit. In the pre-visit phase, the tourist may examine guidebooks, maps and web sites to gain background knowledge about the place that they will visit and plan activities. During the actual visit, the tourist will refer to maps and guidebooks to locate themselves, plan activities and find out more about a particular place of interest. The post-phase of the visit is about reminiscing and sharing the experience with family and friends. Photographs and videos play a central role in the post-visit phase, with occasional references to maps and guidebooks.

A major occupation of tourists is the planning of their activities, both before and during the visit. Unlike work plans, tourist plans are often not too detailed or specific. This not only enables tourists to adapt to any changes in circumstances such as the weather or special events, but also is due to the fact that a major part of the enjoyment of a holiday is discussing and planning what to do and when to do it. In fact, tourists generally travel in groups and there is a high degree of intra-group interaction and collaboration.

Figure 1 shows a typical scenario of two tourists collaborating around a map and a guidebook. They may be either simply finding out about their current environment or planning where to go. One tourist is holding a map and the other a guidebook. The map and guidebook are used in combination. Pointing is used to relate items in the map and guidebook to each other and also to the environment. In some cases, there may be a division of labour where one tourist uses the map to locate where they are, while the



**Fig. 1.** Tourists consulting Map and Guidebook

other tourist looks up something in the guidebook. Often tourists will work together with the map to try and establish their location, specific landmarks or the direction in which they should travel. To do this, frequently often the map is rotated to align it with the physical environment.

It is also important to appreciate that tourists do not simply use maps to plan specific routes. Often it is used as a general reference to the city in terms of areas within the city and their spatial relationship. Tourists may use it to help locate general areas that might be of interest — such as the old part of a city with many small streets or high areas which might provide good viewpoints. In conjunction with a guidebook, they may use it to identify areas with lots of restaurants and bars that might be a good place to wander in the evening. Sometimes tourists enjoy wandering freely, simply following streets that look to be of interest and only using a map or guidebook to find out more information about something they come across or to help them find their way back.

Annotations of maps and guidebooks may also play an important role. Routes or places of special interest may be marked on a map. During the pre-visit phase, selected entries in the guidebook may be highlighted or annotated with some textual comment. Markers may be placed in pages to indicate places not to be missed or information of special importance. Annotations such as simple highlighting, circling or underlining, may be used on both maps and guidebooks to keep a record of places that have been visited.

We have only been able to sketch some aspects of tourist activities involving maps and guidebooks that might influence the design of technologies for tourism. However, there are already a number of factors that we can highlight.

First, it is important to consider the effect of the physical form of technologies. Tourists spend a lot of time combining and comparing information. It is therefore important that they can easily switch back and forth between options and display related information such as map locations and descriptions simultaneously. In the case of the paper guidebook, several places can be bookmarked easily by placing fingers between pages and it is very simple and quick to jump between these pages. As we have seen above, tourists may display paper maps and guidebooks alongside each other simply by holding these next to each other and using pointing to link between the two.

The display option for electronic guidebooks is often a PDA. Comparison of information is rarely offered, mainly because of limited screen size. Further, the reduced size or coverage of maps can make it difficult for users to locate themselves relative to other areas of a city and to plan general directions of wandering. For this reason, some projects have opted for the use of graphical tablets to enable them to provide much richer information environments to the tourists. Clearly the problem here is that, with current technologies, graphics tablets are still relatively heavy if they are to be carried for a significant amount of time and they require the use of both hands. It is important to remember that tourists also want to have hands free, enabling them to carry shopping or hold the hand of an accompanying child or partner.

There are therefore requirements that any mobile devices be light and easy to place in pockets etc. Further, since collaboration is a key aspect of tourism, whether travelling in groups or just asking another person for directions or recommendations, another requirement is that more than one user can simultaneously view and interact with the display. Collaboration around current mobile digital devices is awkward because of both display size and required positioning for clear reading of the display.

Second, the applications developed for tourism need to take into account the nature of the experience. Tourists generally do not want to follow specified routes and fixed recommendations. Discovery is an important part of the experience, as is the social aspect of interacting with both companions and strangers in identifying landmarks and planning activities.

Further, tourists would like to be able to share information with each other. Often recommendations for places of interest, restaurants etc. are included in visitor maps, but these are based purely on advertising. There are many web sites for tourists that enable users to enter and access reviews and recommendations, but data tends to be entered by only a few dedicated tourists in the post-visit phase and access is mainly during the pre-visit phase. It would therefore be useful to have a system that enabled users to more easily enter and share reviews and recommendations during the actual visit.

### 3 Revisiting Paper

Paper consumption in all countries continues to grow despite earlier predictions of a rapid move towards a digital world, culminating in the paperless office. In fact, the average US office worker uses over 10'000 sheets of printing and copying paper each year [14].

A range of studies in the CSCW community have found that even with a wealth of new technologies and attempts to change work practices in accordance with these technologies, paper continues to be central to many activities in the work place, in particular those involving collaboration [21]. More recent studies of domestic environments, classrooms, museums and tourism have also reaffirmed the pervasiveness of paper. Generally, these studies have identified a range of uses and characteristics of paper that seem critical to a whole host of human activities including communication and collaboration.

Paper as a medium has many advantages over digital media in terms of how people can work with it, both individually and in groups. It is portable, cheap and robust. It can be folded, cut and torn. It is much more convenient to scan through a book by rapidly



flicking through pages than to browse a digital document. Paper also supports forms of collaboration and interaction that are difficult to mimic in current digital worlds. One of these mentioned in the previous section is the fact that current displays are best read when viewed straight on — and this makes it difficult for several users to simultaneously view an average or small screen. For this reason, a number of projects in the area of intelligent meeting rooms have focussed on the use of large wall-mounted displays. However, as we have seen with tourists, collaboration is also a factor in mobile environments.

In the world of paper, annotations are heavily used to enhance both reading and writing activities [13]. Annotation is some means of marking up a document so that it augments existing material. Annotations come in many forms and have a variety of uses. They may be private or public, permanent or transient, and formal or informal. Informal annotations often take the form of free text, but could also be sketches. For example, marginalia — the comments that we write in the margins when reading a paper or book — are informal annotations. The use of highlighting, underlining or circling to mark items of interest, as tourists often do with guidebooks or event programmes, is another form of commonly used informal annotation.

Formal annotations follow defined structures and conventions that enable them to be interpreted by other persons or by computer programs. Typographic markup for the editing of documents is one such example. Another example of formal annotation is that used in the semantic web community to markup digital data with metadata [5].

Both informal and formal annotations often provide a basis for communication and collaboration, whether it be part of a co-authoring activity or publishing annotations to aid the interpretation of data or comment on its quality.

There have been a number of proposals to provide annotation tools in the digital world either as part of general web infrastructure [11] or for specific domains or tasks. For example, SAM (Scientific Annotation Middleware) [20] is being developed to provide scientific researchers with a collaborative and cross-disciplinary working environment based around such annotations.

One study examined the task of writing document summaries and how users would annotate the document and take notes [18]. For this activity, readers not only wanted to highlight important items, but also to extract and re-order them according to the final structure of their summary. Annotations alongside the text heavily used references to structure outlines. The study not only examined how readers would use annotations, but also the differences between performing this task using only digital documents as opposed to using only paper. It was shown that there are many problems with digital annotation systems in terms of both inputting the actual annotations and also working with various documents alongside each other.

While there are many advantages to working with paper, clearly there are also advantages offered by digital media in terms of the storage, management, processing, retrieval and distribution of information. For example, although it might be easier to input free text annotations by writing them on paper, the ability to search for annotations and related information could be better supported if they are stored in digital form. For this reason, many researchers have now turned towards trying to integrate paper and digital media in an attempt to gain the best of both worlds. In the next section, we describe various projects and technologies that have been developed in this direction.

## 4 Move Towards Digital Paper

Over the last decade, there have been many efforts to bridge the digital and paper divide. In this section, we start with an overview of some past projects and then go on to discuss the state of the art technology, including both research and commercial solutions.

The Digital Desk was built at Xerox EuroPARC just over a decade ago as an attempt to enhance the physical desk and augment paper [16, 24]. A camera mounted above the desk was used to track a user's interaction with documents and additional digital information could be projected onto the documents. More recent projects that follow on from this idea of an augmented desk have extended the idea with other forms of tracking, such as real-time hand tracking and gesture recognition [12], and the support of specific forms of work activity such as architectural design [2]. Clearly, one of the main limitations of these approaches as far as mobile information environments are concerned is the fact that the documents are augmented only in the context of the physical desk and hence one of the main benefits of paper, namely mobility, is lost.

An alternative approach is to develop technologies based on paper itself and the tools that we use to work with it, particularly pens. DataGlyphs [10, 9] developed by Xerox are a means of encoding digital data on paper by printing images using patterns of forward and backward slashes representing zeros and ones. If the pattern is small enough it is not visible to the reader who sees only the image. However, a special scanning device can be used to read the encodings and activate digital services.

Many systems use some form of printed visible marks on papers as a means of creating links to digital material. For example, standard printed barcodes and a barcode reader have been used in a number of projects to link paper materials with electronic resources (for example [23]). The use of barcodes or other visible encodings has the advantage of clearly making links on paper visible to users. However, this turns out also to be a disadvantage if more than a few links are present and can be extremely disruptive to the reading activity.

Rather than relying on visible link encodings, a means of detecting pen position on paper can be used to both capture writing and activate links to digital content. For example, the mimio Xi [15] designed for whiteboards uses special pens and a high-resolution ultrasonic position detection device to track pen position and this enables handwritten information to be digitised automatically. Seiko has developed a smaller and more portable version called InkLink which can be used for documents up to A4 size. These technologies are essentially page-based rather than document-based and do not provide any mechanism that allows multiple pages to be associated with a document. Therefore while they are suited to the capture of writing, they are less suited to the creation and activation of links between paper documents and digital media.

Another way of detecting positions on paper has been developed by the Swedish company Anoto [4]. The technology is based on an almost invisible pattern of infrared-absorbing dots printed on paper and special digital pens which have a camera as well as a writing stylus. The pattern of dots encodes x-y positions in a vast virtual document address space. Camera images are recorded and processed in real time to give up to 100 x-y positions per second and enable a good representation of handwriting to be captured. Several pages of handwriting can be captured and stored within the pen before being transmitted to a PC. Several pens based on Anoto technology are now available

commercially and these include Nokia's Digital Pen, Logitech's io Personal Digital Pen and Sony Ericsson's Chatpen.

Currently, the focus of commercial products based on Anoto technologies has been on information capture. Hewlett-Packard has recently released a forms automation system based on this technology to reduce the costs of processing and correcting data input via forms in large enterprises such as insurance companies. Although the Anoto technology could be used to link paper with digital content interactively, the fact that current digital pens store data and transmit it only on demand, either by placing it in a cradle or activating special areas on paper, restricts this. However, for the purposes of our research we have been able to obtain a specially modified digital pen that sends data directly and which we can therefore use both for writing capture and general interaction.

From the above discussion, we can see that basically there are two different goals of technologies for digital paper. One is the capture of written information which leads to technologies to support *enhanced writing*. The other is the activation of links from paper to digital resources to enrich the reading activity and hence these technologies can be described as supporting *enhanced reading*. Although technologies such as Anoto have the potential to support both, currently the available pens support only the former. In contrast, within the European project Paper<sup>++</sup> [19] the focus was on enhanced reading and the development of solutions that could be widely deployed in schools, homes etc. This meant that the cost of reading devices should be so low that they would almost be at the level of disposable technologies, i.e. only a few Euros. It was therefore necessary to devise a solution that avoids expensive optical components such as the cameras used in Anoto pens.

The Paper<sup>++</sup> solution uses a grid of almost invisible barcodes printed with conductive ink to encode page number and x-y position within a page. A specially designed pen reads the information encoded in the barcodes by measuring the inductivity and this information is then decoded to obtain the position within a document. So far a few prototype pens have been developed and we have been able to use these in first user studies. However, there are still many open issues in terms of investigating alternative printing and reader technologies to obtain better performance and reliability, while keeping costs low.

Finally, we mention recent developments in display technologies that can be considered as a move from digital to paper in the sense of trying to develop digital technologies with some of the qualities of paper mentioned in the last section. There are considerable efforts to develop screens based on plastic substrates that are extremely lightweight and flexible.

The recently announced Sony LIBRIé e-Book Reader is a first commercial application of Philip's display based on E Ink's electronic ink technology. They claim that it provides readers with a truly paper-like reading experience and can be read in bright sunlight as well as dimly lit environments and viewed at any angle.

## 5 Software Infrastructure

We have seen that there are two aspects to the development of printing and pen technologies to support digital paper, namely supporting the writing activity and the reading