Entry Points into a Smart Campus Environment – Overview of the ETHOC System

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Abstract

The university campus is an interesting application environment for the ubiquitous computing paradigm: a large number of users share a substantial amount of their information needs and much of this information is directly related to physical objects, places, and people that are situated in the campus environment. We motivate the need for material entry points into a virtual campus that increase its accessibility and visibility from within the physical campus environment.

We focus on the aspect of linking virtual and physical elements in such a setting and present the ETHOC system, which enables users to attach virtual counterparts to printed material. The system performs the creation, administration, and intermediation of online resources related to paper documents. To information providers, it offers a Web-based author portal for generating unique IDs that can be printed as barcodes and for associating online content and actions to printed material. To users it offers simple means to interact with virtual counterparts of printed documents using a variety of devices, such as WAP-enabled mobile phones or PDAs, and it stores a personal access history for each user.

The ETHOC system allows us to put ubiquitous computing concepts into practical use and to gain new insights into the design of virtual counterparts of real-world objects.

1 Introduction

The university campus is an interesting application environment for applying ideas from the field of ubiquitous computing [11, 12]. In a campus environment, a substantial number of users share a large amount of their information needs. These needs include information about schedules, locations of class rooms, lectures, assignments, lab equipment, presentations, seminars, sports events, student ads, etc. Much of this information is directly related to objects, places, and people that are situated within the campus environment. The exhaustive installation of wireless computing facilities such as WLAN, together with small handheld devices and technologies for detecting objects or locations, make it possible to satisfy the information needs of users in a campus environment in new ways.

This paper provides an overview of the "Entry Points"[1] project, which deals with applying ubiquitous computing ("ubicomp") ideas to a campus environment. It is part of a larger initiative at ETH Zurich, named "ETH World"[2], the goal of which is to establish a virtual campus in addition to the existing physical campus. ETH World plans to provide a virtual environment that sustains the university community, supports research, teaching and learning, unifies various university services, and is used by everyone working or studying at ETH Zurich.

While the World Wide Web with its manifold services in the area of teaching and research exists mainly in the virtual world, a *ubicomp campus infrastructure* is supposed to augment the physical campus infrastructure and to be closely related to the physical entities, places, and people within it. To achieve a close coupling between physical and virtual campus, not only the parallel development of physical and virtual architecture are needed, but also their dense interweaving.

By embedding *physical hyperlinks* into the campus and attaching information to physical objects, visible entry points into the information space are created, enabling a natural interaction between the physical and the virtual en-

[1]See http://www.ethworld.ethz.ch/nw/projects/details/137
[2]See http://www.ethworld.ch

vironment and thus providing ubiquitous access to it. By linking the virtual to the real world, new interaction patterns emerge on both sides.

In this paper we focus on the aspect of linking virtual and physical elements in a campus environment and present the ETHOC system, which was developed as part of the Entry Points project. "ETHOC" stands for "EveryThing Has Online Content" and enables users to attach online information and functionality to printed documents.

2 Providing Entry Points into a Ubicomp Campus Environment

In [5], Fitzmaurice discusses *situated information spaces* – real environments, in which electronic information is associated and collocated with physical objects that act as *information anchors* and provide a means of partitioning and organizing the information space. They provide "hot spots", which are roughly equivalent to what we call *entry points*, and serve as retrieval cues for users. The result is that information is situated and grounded in the physical context to enhance user orientation and ease of use.

A virtual campus as we envision it can be seen as an instance of a situated information space. For the usefulness and usability of a virtual campus it is vital to make it accessible from the physical objects and the physical environment of the people involved. To reach this goal, visible entry points are embedded into the physical campus environment that lead to items in the virtual campus infrastructure. The visibility of the entry points ensures that the virtual campus is present in the consciousness of its users and used in an everyday manner.

A way to realize this is to attach so-called *physical hyperlinks* to physical entities. Physical hyperlinks couple real objects to *virtual counterparts* which represent physical objects in the virtual world and provide online resources and online functionality. Virtual counterparts also process events and capture relationships with other virtual counterparts. Relationships between virtual counterparts are dynamic and evolve over time as a result of user actions and other events.

Potential relevant information related to physical objects might concern place and time as well as object-specific information or online information on the Web [2]. Examples for such couplings in the context of a university are

- lecture halls that are associated with their occupancy status and reservation plan;

- technical equipment that is connected to its maintenance schedule or usage information;

- flyers, posters, and announcements that are linked to background information, electronic calendar entries or

ticket reservation systems; and

- lecture handouts and exercise sheets that are coupled to related multimedia content or exemplary solutions.

Not only passive information, but also online functionality and actions can be triggered when following a link from the physical object to its virtual counterpart. This includes, for example, performing reservations, storing calendar entries on the user's mobile device, triggering email messages, or signing up for event notifications.

To effectively support the everyday activities in research and teaching, the members of the university community have to be given the opportunity to actively participate. An easy-to-use system is needed that enables students, assistants, faculty, and staff

- to augment printed material they create as well as physical resources they use for teaching and research by online content and functionality, and

- to interact with the virtual resources using a variety of mobile and stationary devices of potentially limited capability.

These general ideas form the foundation and starting point for the ETHOC system.

3 Overview of the ETHOC System

After having introduced the concepts of entry points and virtual counterparts in the previous section, we now give a general description of the ETHOC system and a detailed motivating example of how it might be used.

In its current form, ETHOC focuses on paper documents as instances of popular real-world objects of a university campus. The tasks that ETHOC performs are the creation, administration, and intermediation of online resources related to such documents. The system has two interfaces: one for information providers and another one for information users. The first interface is a Web-based author portal for generating and embedding ETHOC barcodes into documents. It also takes care of managing associated online content and document meta data and of specifying the associated actions. The second interface offers simple means to interact with virtual counterparts using a variety of different devices. Examples range from WAP-enabled mobile phones equipped with attached barcode readers, over PDAs with wireless connectivity, to the full fledged ETHOC browser for Java-enabled PCs and laptops.

The following scenario illustrates the usage of the ETHOC system from the author's as well as from the client's perspective:

Bob has just graduated and decides to sell some of his stuff via the student bulletin board before he moves out. He prepares the ad with his favorite word-processing program, including a short description of the items on sale, his address, and a date for the sale. He uses ETHOC's author interface to get an associated ETHOC barcode – formatted as a gif image – which he inserts into his ad. Bob enters his contact information and the date and time for viewing the items on sale. Additionally, he takes some pictures of the items and uploads them to the ETHOC system. Finally, he uploads the ad, prints it, and sticks it to the student bulletin board.

Meanwhile, in Alice's introductory computer science class, lecture handouts and exercise sheets are distributed. They contain ETHOC barcodes that are linked to a newsgroup for discussing the exercises, to a source code skeleton needed to solve the programming assignment, and to survey articles relevant to today's class. Alice scans the codes with a tiny barcode reader that is attached to her mobile phone and the links are stored in her personal online history.

After the lecture, a poster announcing an interesting talk attracts her attention. She scans the attached code with her phone. The talk is added to her personal history and a WML page is instantly displayed, shortly describing the speaker's bio as well as directions to the lecture hall. It also indicates that the location of the talk has been rescheduled. Clicking on an item labeled "appointment" inserts an entry for the talk into her mobile phone's calendar. A little later she spots a posting on the student bulletin board announcing various things for sale. She quickly scans the ETHOC code to store it in her access history and decides to look at it later.

At home she connects her laptop to the Internet and – using the ETHOC Java client – looks at the items she has scanned today. She selects the sale entry and looks at the pictures of the items. Using the contact information, she calls Bob for an item she is interested in and verifies the date and time for the sale.

After selecting the exercise entry, the source code skeleton for the programming assignment is automatically downloaded. Following the resource links, she finds two papers that discuss an aspect of today's talk in detail. At the exercise newsgroup she posts a question about a particular topic she did not understand in the lecture.

The next day she is having a coffee with friends at the cafeteria, when suddenly the alarm on her mobile phone goes off. It is the reminder for the talk that she would have missed otherwise.

The scenario illustrates the notion of *environment-mediated communication (EMC)* [6]: Electronic information is dispersed throughout the environment, enabling casual interaction and anonymous communication. Information dispersed in this way is bound to a physical object or location and therefore reduces information overload. Information is organized according to physical entities and information of only local relevance is filtered by location.

The short interaction time of just scanning an item that is then automatically inserted into a personal online history is crucial for usability in a mobile environment. It does not require much effort and takes just a few seconds. The user can later review the scanned items and is not distracted from the current activity.

The scenario also shows that a variety of devices can be used to interact with the virtual counterparts. Information that is situated in a real world context can be picked up in the originating context using an unobtrusive mobile device. The information can later be reviewed and interacted with in another, more suitable situation, using a stationary device with better display capabilities. That way, mobile and stationary devices complement each other. The former having severely limited size restrictions and interaction capabilities, but being easy to use in a mobile context of an everyday real-world situation. The latter being out of context, but offering richer user interface capabilities.
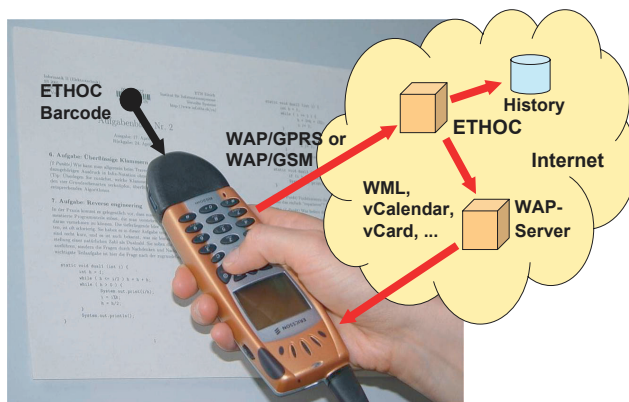

Figure 1. Scanning an ETHOC code using a mobile phone with an attached barcode reader

The majority of the information picked up might be immediately useful to the user in his / her current situation while some information might be more useful at a later

point in time, potentially in another context. ETHOC supports this by the automatic storage in the user's personal online history of scanned objects.

Fig. 1 shows what happens when the user scans a barcode with a mobile phone. The wireless communication technology is WAP over GSM/GPRS in this case, but might also be WLAN or Bluetooth. The scanned ETHOC ID is sent as part of an HTTP request to the ETHOC server. In addition to the ID of the scanned object, the request contains information about the client device capabilities, which is used to render the result in a format the client can display.

The ETHOC server stores the scanned ID in the user's personal online history, where it is available for later retrieval with other devices. Depending on the device capabilities, an HTML or WML page that contains hyperlinks to the document's online content is generated and sent back to the client device. By following the links, the associated online content – e.g., background information, contact information, or calendar entries – can then be retrieved. Which functionality of the virtual counterpart is available at a time depends on the device currently in use; the automatic insertion of a calendar entry, for instance, may only make sense for a mobile phone or PDA, but not for the Web browser used in a public Internet café.
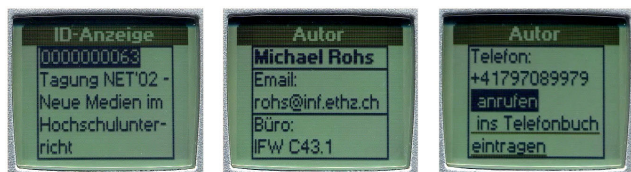

Figure 2. On the mobile phone, a WML page is shown as the result of scanning a paper document

Even though the display size of current mobile phones is severely limited, they are a useful tool in the showcase described above. Using the standard vCalendar [4] format, calendar entries can automatically be inserted into the user's personal calendar to act as reminders for deadlines or events. Using the vCard [3] format, phone calls can immediately be placed. Last but not least, WML has capabilities that come close to those of HTML. Fig. 2 shows a document as displayed on a mobile phone. The left screenshot shows the ETHOC ID and the title of the document, the middle and right parts show information about the document author. The user can store the author's address in the calendar of the phone.

4   Architecture

In this section we give an overview of the system architecture, describing the main system components that can be categorized as XML-based data processing, authoring support, client support, and back-end data management.

XML-based data processing.   The generic description language XML was chosen to model the data structures of virtual counterparts of arbitrary objects in the ETHOC system. XSL transformations (XSLT) are used to convert internal XML data structures into client-readable data representations. For each object type different XSLT descriptions are stored in the ETHOC database, e.g., for HTML, WML, or XML data representation, together with suitable mappings for various client devices. Then, whenever a document is requested, the type of the client (or user agent) is evaluated and the data transformed corresponding to the best matching XSLT description.

XML is also used to store and maintain the configuration of system components in a flexible manner. The number and type of modules available in the authoring portal is stored in an XML document, for example, which can be edited to add new tools or modules. As a side effect, the broad range of advanced tools for parsing, processing and transforming XML (e.g., see [13, 14]) contribute to the versatility of XML-based data processing. With respect to virtually augmented documents, the XML structure of a virtual document counterpart consists of four main sections: author information, document related information, contact information, and actions.

Authoring support.   The authoring portal[3] provides authors with tools to create and modify documents and to edit the personal profile. In addition, the authoring support also includes modules for author registration and authentication.

After successful logon, an author may either create a new or edit an existing virtual document counterpart. In the first case, a new minimal XML document is generated, and the user is guided through different forms to fill in required and optional information. In the second case, the existing XML document is loaded and displayed. In both cases, the editing process operates directly on the XML representation of the document counterpart. With respect to its structure, the XML document is divided into different sections. For each document section there exists a distinguished module, represented by a separate servlet application which is in charge of displaying and editing the current document fragment, and of the transformation and validation of the data entered by the author. An author may either follow a preconfigured sequence of authoring tools to complete a new counterpart
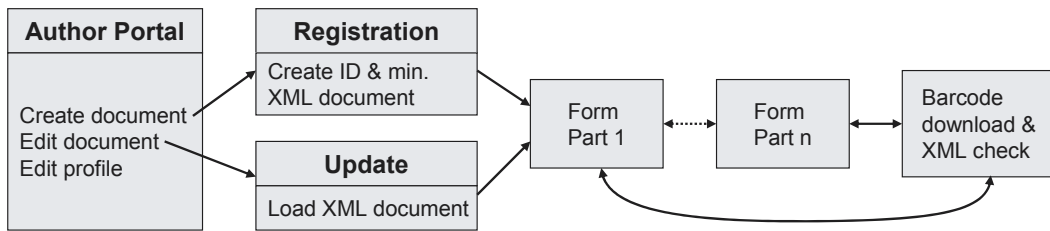
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[3]See http://ethoc.ethz.ch

Figure 3. Flow of operation for the registration of new documents or to edit and update existing documents in the author portal

or just select the modules of interest. Once the author has entered all obligatory information, he / she can download an ETHOC ID (barcode) and insert it into the version of the document that is to be printed. Before a new document counterpart is activated, a summary of the added meta data and selected functions is presented by a special finalizing servlet.

The possible operation sequences for the creation or modification of virtual document counterparts in the author portal are illustrated in Fig. 3. The document counterparts are edited in different form parts. The functionality of each stage in the diagram, including the various form parts, is performed by an independent module. New modules can be introduced by updating the global configuration (XML file) of the author portal.

Currently, the following authoring tools (modules) have been implemented for virtual document counterparts: *author notification* for life cycle management support, *feedback questionnaire*, *news client* to read or write news articles related to the current document.

Client support. The ETHOC system supports three different ways to access the virtual counterparts of physical documents. First, it provides a Web-based user interface that can be used on any device with an installed standard Web browser. Second, for small, resource-limited mobile devices such as mobile phones, a WML interface has been implemented. Since small devices often have limited capabilities, e.g. lacking a viewer for PDF or PostScript documents, and due to the restrictions imposed by WML, the WML portal only grants access to a limited number of features and information of a document counterpart. Third, for devices that are capable of running Java, e.g. laptops or PDAs, there is a designated application, the ETHOC Browser (see screenshot in Fig. 4), which provides advanced features such as document caching and automatic synchronization if document updates occur on the ETHOC back-end server.

If the client configuration and the available hardware permits, a barcode on a document may be scanned automati-
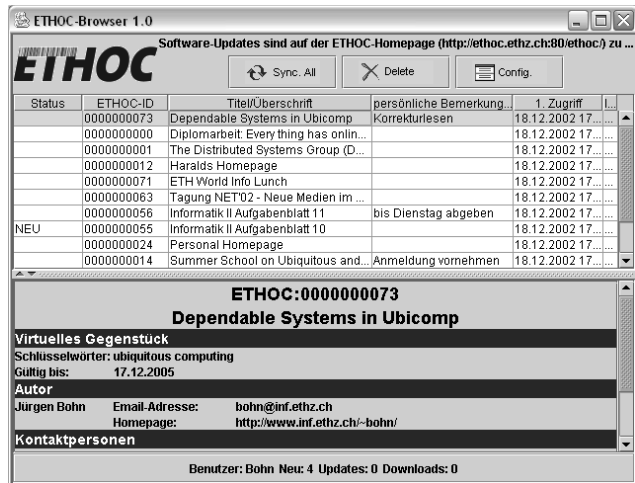

Figure 4. Screenshot of the ETHOC Browser

cally by means of a mobile barcode reader. Otherwise, all clients offer a user interface for manual input of the corresponding numeric barcode value.

Back-end data management. An important task of the ETHOC system is the management and persistent storage of virtual document counterparts, that is the XML descriptions together with the attached objects (files, movies, etc.). The back-end database system – we use MySQL for that purpose – keeps track of all documents that are viewed by a person, maintaining a personal history for each user. Further responsibilities of the back-end data management include the accounting of assigned ETHOC codes and the administration of user profiles.

5 Results

As we have seen, the ETHOC system provides *entry points into a virtual infrastructure* by linking physical documents to virtual counterparts. We have also described how

a modular design contributes to an increased *flexibility* and *extensibility* of the system.

By supporting a variety of heterogeneous clients and ubicomp devices, the system allows accessing the virtual object counterparts in various different situations and locations, e.g. in an Internet café using a Web browser, on the train using a mobile phone, or at a communication hot spot at public places, e.g. at the airport or train station, using a PDA with wireless LAN or Bluetooth connection. And, because of fully interchangeable clients and with help of the user's personal access history, any other client is suitable to retrieve the information on previously scanned documents in case a device has been left behind unintentionally or even gets lost. This user-friendly behavior increases the *ease of use* of the system.

At the same time, these characteristics also positively influence the reliability of the system: By allowing the interchanging use of multiple clients, a *diversification* of the information access is achieved: devices may be lost or broken, but the information that has been retrieved once remains accessible. While a user may own just one device of a certain kind (e.g., one mobile phone, one PDA, or one laptop), the functionalities of all his devices usually overlap when taken together. As a consequence, the various devices that feature some kind of wireless communication capability can be used independently from each other to connect to the ETHOC service, reducing the dependence on a single device or technology. Thus the heterogeneous redundancy of the available devices is exploited, yielding a higher *accessibility* and *availability* of information on the client's side.

Furthermore, the ETHOC system explicitly supports *disconnected operation* of all mobile client devices that possess a standard Java Virtual Machine to run the ETHOC browser application. The ETHOC browser performs local caching of on-line resources for off-line operation later on, including an automatic synchronization of documents updated on the server or newly scanned in with a barcode reader.

5.1 Lessons Learned

At present, we mainly use barcodes as the underlying identification and linking technology since they proved to be very practical: They can be printed on paper and do not require special (pre)processing, as is the case with passive radio frequency identification (RFID) tags which need to be initialized and have to be manually attached to documents. Even so, we think that alternative identification technologies may be more suitable for other object types, e.g. active radio beacons could be used to tag rooms or other locations.

Also, instead of requiring the author to manually place an ETHOC barcode inside the documents, we are considering to implement a printer driver that combines the authoring procedure with a fully automated barcode integration.

Concerning practical experiments, we annotated exercise sheets with ETHOC codes in an undergraduate lecture. This allowed us to timely provide source code fragments and exemplary solutions to students. By means of the integrated news client module, we successfully setup custom news groups for the discussion of specific exercises and coupled them with the corresponding exercise handouts. Apart from these promising initial experiments, the system is not yet applied on a day to day basis. We wish to expand its usage in the future especially to non-expert users, i.e. students from fields other than computer science.

In our group we further experienced that the perceived convenience, usefulness and fun factor increased noticeably with the availability of barcode scanner devices for automatic barcode scanning, such as a mobile barcode reader attached to a mobile phone or a small and handy wireless barcode scanner. In this respect the extra costs for the required add-ons still constitute a handicap, especially since popular consumer products such as PDAs and mobile phones are not equipped with barcode scanners per default today.

5.2 Related Work

At Xerox PARC the *ParcTab* ubiquitous computing environment [10] was established to augment everyday artifacts by computational capabilities. Want et al. [9] describe various techniques that were used in that system to couple the physical and the virtual world. Paper documents, books, and other artifacts were equipped with RFID tags and related to corresponding Web pages and services. In ETHOC we use barcodes, because they are easier to handle and are well suited to being printed together with the paper document.

HP's *cooltown* project[4] is a pragmatic approach for the realization of "smart" environments, in which physical and virtual worlds move closer together. The goal of the *cooltown* project is to establish a "real" world wide web, in which users can pick up URLs that are embedded in the real world and in which people, places and things have an immediate presence [8]. Unlike in ETHOC, the virtual counterparts are just Web pages in this model.

In the *Sentient Computing* project[5] [1] of AT&T Laboratories so-called "smart posters" have been developed. Smart posters are printed and attached to a wall and contain sensitive areas that are linked to specific actions. A small handheld device called "bat" is used to select a sensitive area. The *Sentient Computing* system is based on an ultrasound location system and is rather expensive to install. In contrast to that we focused on cheap and immediately deployable technologies that require less effort.

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[4]See http://www.cooltown.com
[5]See http://www.uk.research.att.com/spirit

The *WebStickers* system [7] uses barcode stickers to access and organize bookmarks on the Web. The stickers are attached to everyday objects that act as physical representations and reminders of the associated Web pages. The bookmarks are therefore organized according to the context of the physical workspace.

To our knowledge, besides *WebStickers* in a limited way, none of the systems mentioned above provides an authoring interface that allows a group of people to actively engage in the content generation and publication process. Yet we consider it as crucial that the people interacting with the system are also in a position to actively design their information environment. As described above, ETHOC provides a Web-based author portal for that purpose.

6 Conclusion

We believe that ETH World offers an ideal deployment environment for our research. It makes possible to involve a large number of users and to have an immediate impact on the development of the university community. To achieve short-term results and stimuli for further research issues, we focused at the start of our project on technologies that are immediately available.

While in the current version of the ETHOC system we mainly dealt with document-type objects and their counterparts, the overall architecture has been designed with the intention to support arbitrary real-world objects. In future versions of ETHOC, we plan to extend the range of supported object types and authoring modules. We also intend to investigate concepts of context-aware retrieval of online content, such that the provided information that a user receives not only depends on the ID of an object, but also on context like the identity or location of the person.

Our main research goal is to get insight into the design of virtual counterparts and the interaction with smart environments. For further information, please visit the Web page of the Entry Points project and the ETHOC system at:

<div align="center">http://ethoc.ethz.ch</div>

Acknowledgements

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